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Report on an Automated Calibration Range for Broadband Isotropic Probes

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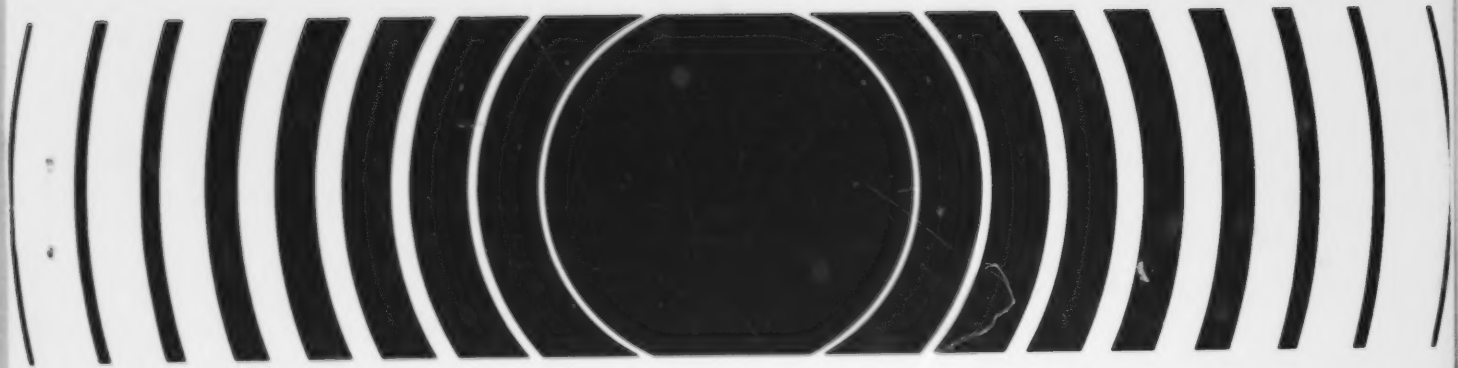

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This report describes the construction of an automated absolute field generation system using standard gain horns and an anechoic range. This system operates in the frequency range of 1.12 to 26.5 GHz. The primary purpose of the range is automated evaluation of the frequency response and isotropy of various commercially available microwave hazard survey meters.

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Report on an Automated Calibration Range for Broadband Isotropic Probes

by
Jerry Johnson

May 20, 1983

U.S. Environmental Protection Agency
Nonionizing Radiation Branch
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DISCLAIMER

Although the work described in this document has been funded wholly by the United States Environmental Protection Agency it has not been subjected to the Agency's required peer and policy review and therefore does not necessarily reflect the views of the Agency. No official endorsement should be inferred.

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ABSTRACT

The Nonionizing Radiation Branch of the U.S. Environmental Protection Agency conducts a program to assess environmental exposure levels of radiofrequency fields and to develop regulatory standards to limit the exposure of the general population to these fields. An essential element of this program is the maintenance of an electromagnetic field measurement instrumentation calibration and evaluation capability. This report describes a development project of a standard gain horn anechoic range system for evaluating the response of broadband, isotropic microwave measurement probes to accurately known electromagnetic fields. This project involved the development of a computer controlled system for generating, known electromagnetic field intensities. This system provides a convenient and accurate method to evaluate measurement probe response to microwave fields and therefore establish uncertainty limits for instrument readings obtained in hazard survey measurements.

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PURPOSE OF PROJECT AND INTRODUCTION

An integral function of the Nonionizing Radiation Branch (NRB) of the United States Environmental Protection Agency (U.S. EPA) is the measurement of intense electromagnetic fields to which the population may be exposed. The devices most commonly used for these measurements are broadband electromagnetic hazard survey meters, such as the Narda Model 8616 electromagnetic radiation monitor with a Narda Model 8621 broadband isotropic probe. It is important to determine the absolute accuracy of these electromagnetic (EM) hazard survey meters for measuring microwave fields, when exposed to a variety of electromagnetic radiation environments. It was decided that development of an in-house calibration and evaluation system was necessary to accomplish such evaluations. This report documents the development of a computer automated system for generating accurately known microwave field intensities and provides some limited test data which illustrate the practical application of the system.

Before the subject of EM calibration is discussed, a brief discussion of the broadband radiation monitor (BRM) is necessary. A BRM is an instrument which may be handheld and operated from it's own power source. Such a device usually outputs an analog signal indicating the power density or field strength of the field it is exposed to in it's frequency range. Because of their practical application in assessing possible microwave radiation hazards, they are being employed in greater numbers, often by relatively inexperienced personnel.

There are three practical approaches to establishing EM calibration fields: transverse electromagnetic (TEM) cells, waveguides, and standard gain horn anechoic range systems. These three types of systems can overlap in frequency ranges depending upon their physical sizes. This report will concentrate on the standard gain horn anechoic range system operating in the frequency range of approximately 2 to 12.4 GHz. It's operation will perform the field generation, data acquisition, and BRM calibration.

To date, much of the work has been done on automating and characterizing the standard gain horn anechoic range system, although some system components still require standard laboratory calibrations to increase confidence in the system's results.

This report documents field strength expressions applied, theoretical and experimental gains of the horns used, measurements of calibration parameters of system components, a system description, testing, and a sample application of the automated standard gain horn anechoic range calibration system.

STANDARD GAIN HORNS

A commonly used approach to calibrating RF monitors at frequencies above 1 GHz is to generate a calculable field using standard gain horn antennas. These antennas are configured as pyramidal horns (see Figure 1). The pyramidal horn near-field gain is necessary because the power levels that would enable calibration to take place in the far-field would typically exceed 1 kW. A simple formula for calculating near-field gain is then a requirement.

Some complications arise when trying to calculate the field strength in the near-field. The label for this complication is near-zone gain reduction. The electromagnetic field across the horn aperture has more of a spherical shape then a plane wave shape. The phase at the rim of the horn lags that at the center of the horn. This causes a nonequiphase front across the aperture which in turn reduces the horns effective gain in the near-field region. In the far-zone region of the antenna, plane-wave conditions exist and:

$$S = \frac{PG}{4\pi d^2} \tag{1}$$

where:

P = Power delivered to the transmitting antenna, watts,

G = Gain of the horn,

d = Distance from the antenna aperture to the field point, meters,

S = On-axis power density of the radiated field, W/m^2.

Fresnel integrals are sometimes used for solving problems in optics and fields near aperture antennas. These integrals are very complex and cannot be

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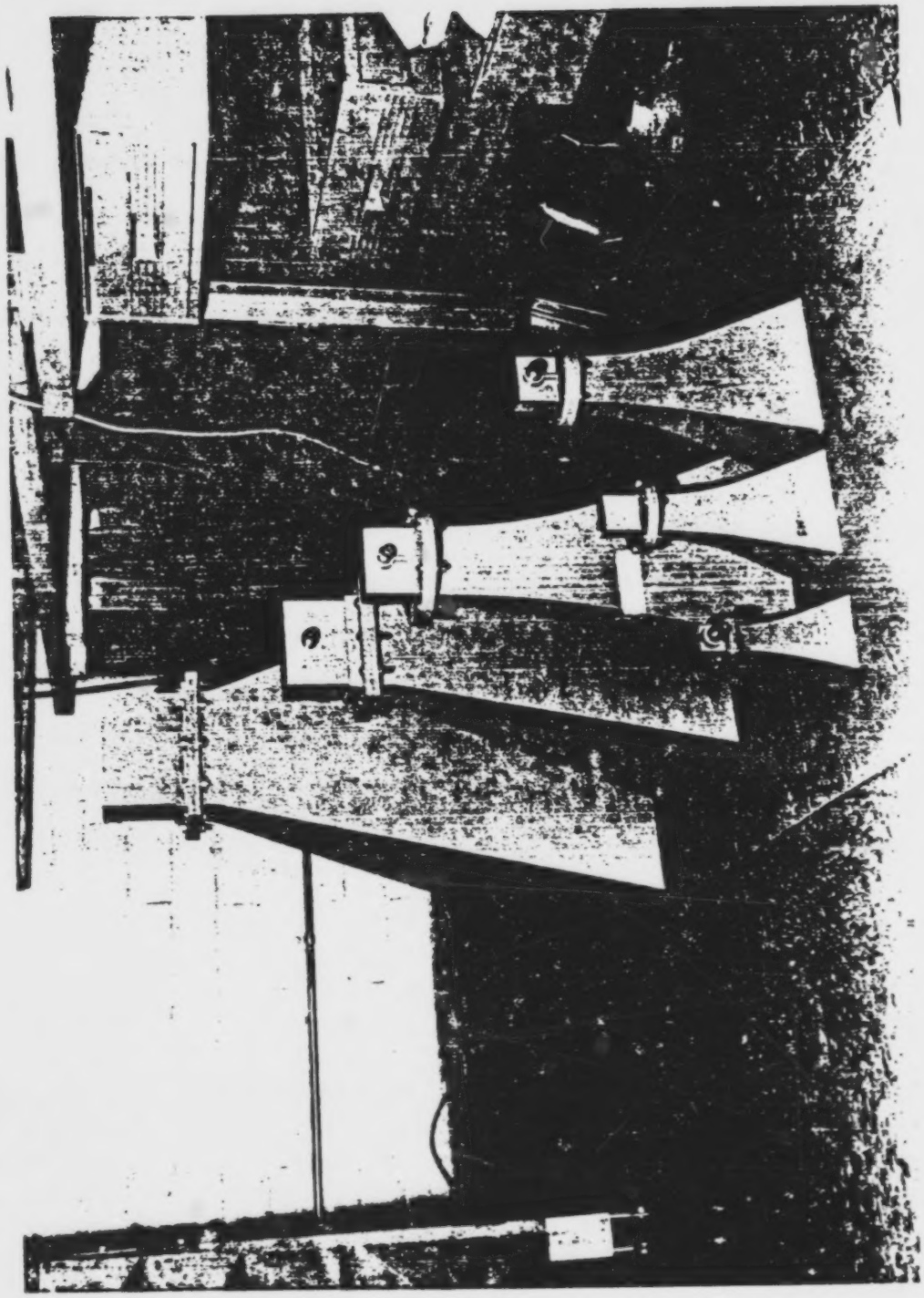

Figure 1. Picture showing the series of standard gain horns to be used in this project

evaluated easily without a computer. Mathematical approximations have also been given for the Fresnel integrals. Some of these approximations involve infinite series expansions, and some others involve combinations of trigonometric and algebraic functions. Recently a short paper was published by E. V. Jull which gave tables of values for near-zone gain reduction factors of pyramidal horns. Jull's technique begins with an equation for the far-zone gain of a rectangular in-phase aperture. Then, two individual factors, R_H and R_E, are generated for the gain reduction due to the H-plane and E-plane flare of the horn.

E. B. Larson recently did some work in this area of concern. He generated simple polynomial expressions, similar to the algebraic equations which have been published for approximating the Fresnel integrals, for determining these R_H and R_E factors. The horn dimensions that are needed for this calculation are shown in Figure 2. The dimensions have been normalized to wavelengths by letting:

$$A = \frac{a}{\lambda}, \quad B = \frac{b}{\lambda}, \quad L_H = \frac{l_H}{\lambda}, \quad L = \frac{l_E}{\lambda}, \quad \text{and}$$
$$D = \frac{d}{\lambda} . \tag{2}$$

Where:

a, b, l_H, and l_E = Horn dimensions, meters,

d = Distance from the horn aperture to the field point, meters, and

λ = Free-space wavelength, meters.

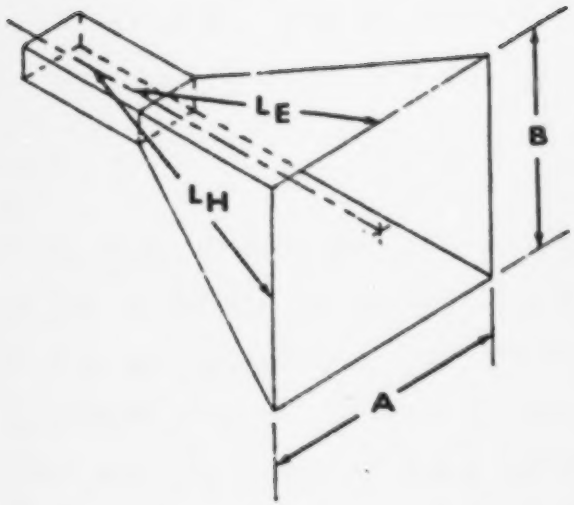

Figure 2. Standard gain horn dimensions used in computation of near-field gain [taken from Larsen (1979)].

After determining:

$$\alpha = A^2 \left(\frac{1}{L_H} + \frac{1}{D}\right) \quad \text{and} \quad \beta = B^2 \left(\frac{1}{L_E} + \frac{1}{D}\right), \tag{3}$$

the two gain reduction factors R_H and R_E are then, in dB:

$$R_H = (0.01\alpha)\ (1 + 10.19\alpha + 0.51\alpha^2 - 0.097\alpha^3) \tag{4}$$

(Due to H-plane flare of horn)

$$R_E = (0.1\beta^2)\ (2.31 + 0.053\beta) \tag{5}$$

(Due to E-plane flare of horn).

The final equation for the theoretical gain of the horn (near zone or far zone) is given by Larsen as:

$$\text{Gain, dB} = 10 \text{ Log } (AB) + 10.08 - R_H - R_E. \tag{6}$$

During this project a computer program was developed to generate values of gain of the horns to be used as transmitting antennas. This BASIC program is listed in Appendix A. The program calculates gain at any distance and any frequency using equations 2, 3, 4, 5, and 6. It also plots the gain in a cartesian coordinate system. Some typical runs of the program may also be seen in Appendix A.

THE TWO HORN TECHNIQUE

To build confidence in the method for calculating near-field gains it became necessary to generate some experimental data on the gain of the horns to be used in the actual calibration range systems. A commonly known method referred to as the two horn or two identical antenna technique was used to test the data obtained from the program. Briefly, this technique envolves using two horns that have identical dimensions. With identical dimensions the gains of the two horns are identical. One horn is used as a transmitter and the other is used as a receiver. An algebraic expression is then used to derive the experimental gain of both horns. The gain of the horns is directly related to the power transmitted by one horn and the power received by the other horn.

The power density, S, in the direction of maximum radiation from a transmitting antenna is given in equation (1).

Solving Eq. (1) for P_t yields:

$$P_t = \frac{4\pi d^2 S}{G_t} \qquad \text{where:} \quad G_t = \text{gain of the transmitting horn} \tag{7}$$

A similar expression exists for the power received:

$$P_R = \frac{4\pi d^2 S}{G_R} \qquad \text{where:} \quad G_R = \text{gain of the receiving horn} \tag{8}$$

Relating Eq. (7, 8) to voltage and impedance yields:

$$V_t = P_t Z = 4\pi d^2 Sr/G_t \tag{9}$$

$$V_R = P_R Z = 4\pi d^2 Sr/G_R = PA_r Z \tag{10}$$

Where:

Z = impedance, ohms,

V_t = transmitting voltage, volts,

V_R = received voltage, volts,

A_r = effective radiating area, cm^2,

P = net power, watts.

When the ratio of the transmitting and receiving voltages are formed from equations (9) and (10), the results are:

$$\frac{V_t}{V_r} = \frac{4\pi d^2 Sr/Gt}{S_r A_r r} = \frac{4\pi d^2}{A_r G_t} \tag{11}$$

When:

A_r = receiving antenna aperture area, $meters^2$.

When substituting $A_r = \lambda^2 Gr/4\pi$ into equation (11), equation (11) becomes:

$$\frac{V_t}{V_r} = \frac{4\pi d}{\lambda G} \qquad \text{when: } G = G_r = G_t \tag{12}$$

$$\text{or } G = \frac{4\pi d/\lambda}{V_t/V_R} \tag{13}$$

By using $V_t = P_t r$ and $V_R = P_R r$ equation (13) becomes:

$$G = \frac{4\pi d}{\lambda} \frac{P_R}{P_t} . \tag{14}$$

Equation 14 is applied in order to obtain, by measurement of P_t and P_R, the gain of the antenna. The system set-up is shown in figure 3. The test area is between two anechoic walls to achieve no erratic data due to unwanted reflections.

The test is run for each desired frequency. Above 1 GHz it is generally only necessary to run the test in 1 GHz steps. The following step-by-step procedure was used to derive the experimental gain of the transmitting and receiving antennas:

1. Adjust the RF level of the RF generator until a reading is obtained from the receiving antenna.

2. Adjust the alignment of the horns until a maximum receiver reading is obtained.

3. Take measurements of forward power and received power.

4. Make a measurement of the distance from the aperture of the transmitting antenna to the aperture of the receiving antenna.

5. Use equation (14) to derive a value of gain.

6. Starting from approximately 2 wavelengths distance between the antennas, measurements should be made at approximately 1 wavelength distance increments.

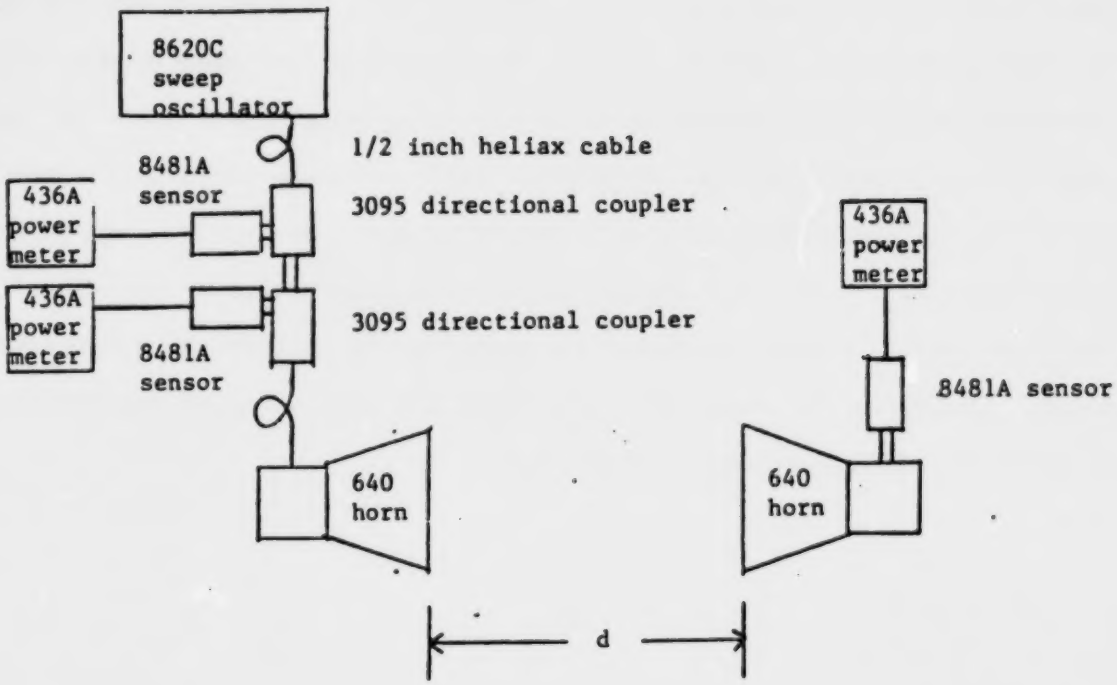

Figure 3. Block diagram of system used to derive experimental gain of horn antennas

This test was made at a frequency of 10 GHz. Two Narda Model 640 horns were used. The results obtained from experimentation are plotted in Figure 4. The solid line in the plot represents the theoretical gain of the Narda Model 640 horn as obtained from application of Equation 6. The segmented curve represents the data obtained from the two horn gain measurement technique. At three wavelength distance between the apertures, the experimental data disagrees with the theoretical data by approximately 0.8 dB. At five wavelengths distance between the apertures the experimental data disagrees with the theoretical data by approximately 0.3 dB. At the wavelengths greater than six wavelengths, the experimental gain data appears to follow the theoretical data with errors so small they become negligible. The data plotted in Figure 4 are assumed to be representative of theoretically and experimentally obtained near-field gains to be used in the calibration range. Duplicates of every horn size were not available, so experimental gains could not be generated for every horn.

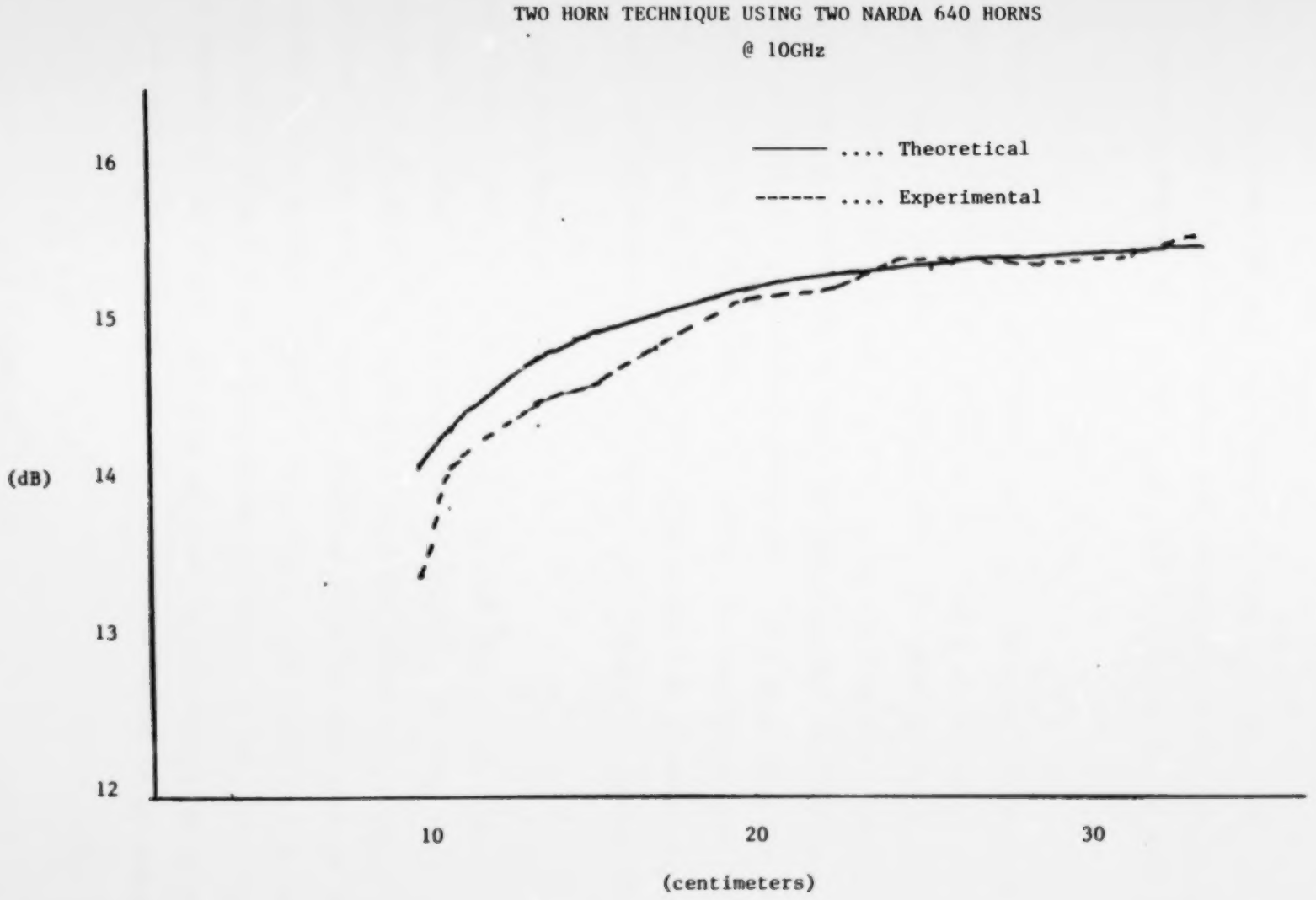

Figure 4. Theoretical versus experimental horn gains

RANGE REFLECTIONS

The range is basically two walls that are mounted on wheels to enable easy movement of the walls. The front wall has shelves mounted on it to support the equipment used for generation and measurement of the signal used to create the electromagnetic fields. See Figure 5. The inside face of the walls are covered with an anechoic material which is specified to be relatively non-reflective. See Figure 6. The space between the two walls is the medium in which the field is to be propogated. The front wall is approximately 8 feet high and 4 feet wide. The back wall is approximately 8 feet high and 8 feet wide.

The physical existence of environmental surroundings can create many errors in determination of the absolute field intensity of microwave fields. Reflections were of a main concern in the project and substantial effort was expended to quantify the influence of reflections. Such reflections can come from a variety of sources such as the floor, the laboratory, and the anechoic walls. Because the antennas used are highly directive, typically possessing a 28 degree beam width at the 3 dB (half-power) points, there is not as much of a need to center attention to reflections other than those that exist due to the anechoic material. A test procedure is then needed to evaluate these range reflections.

The basic approach used in evaluating range reflections was to hold the receiving probe at a constant distance from the aperture of the horn antenna and move the receiving wall with respect to the other wall and observe

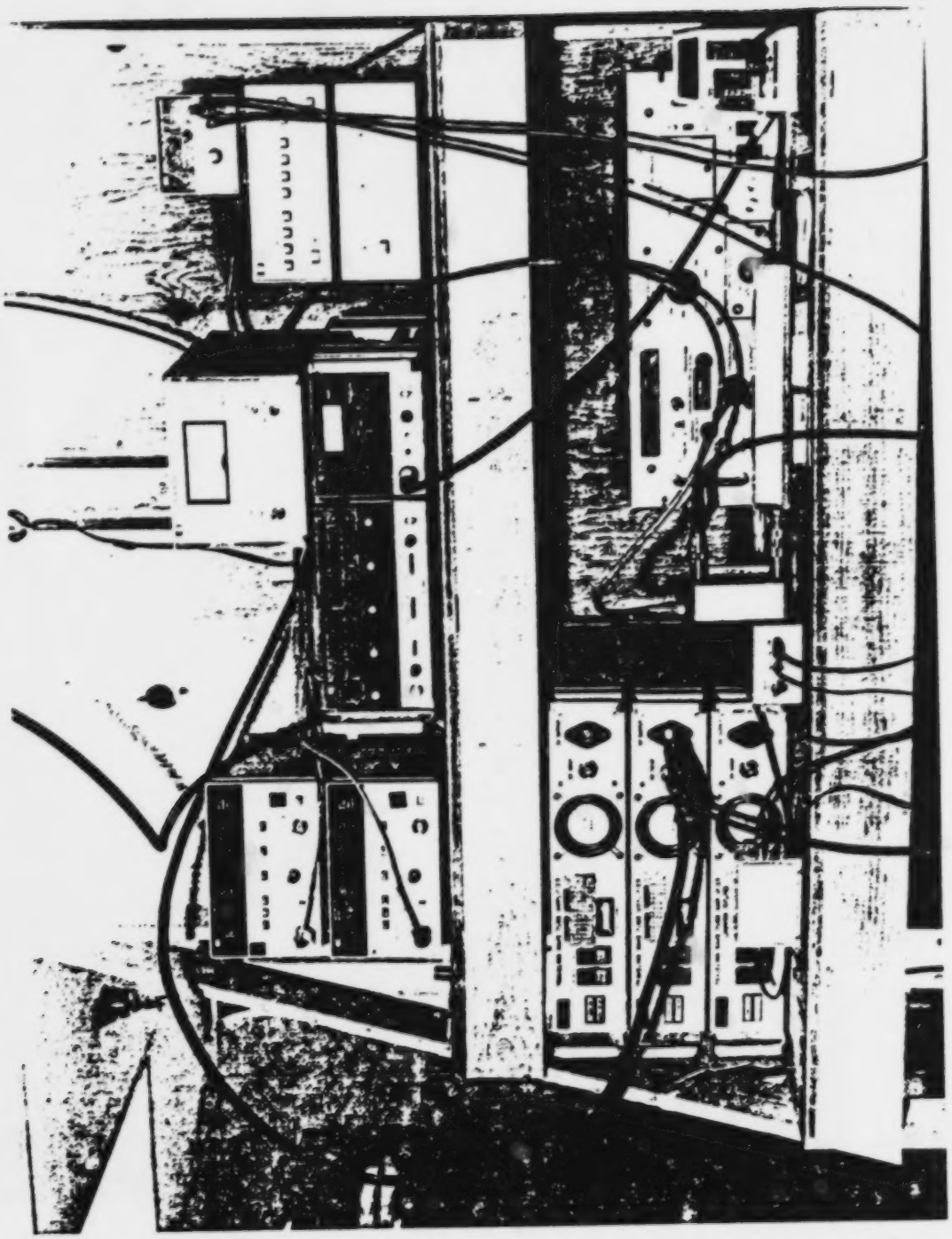

Figure 5. Picture showing the shelves on the front wall used to support the equipment.

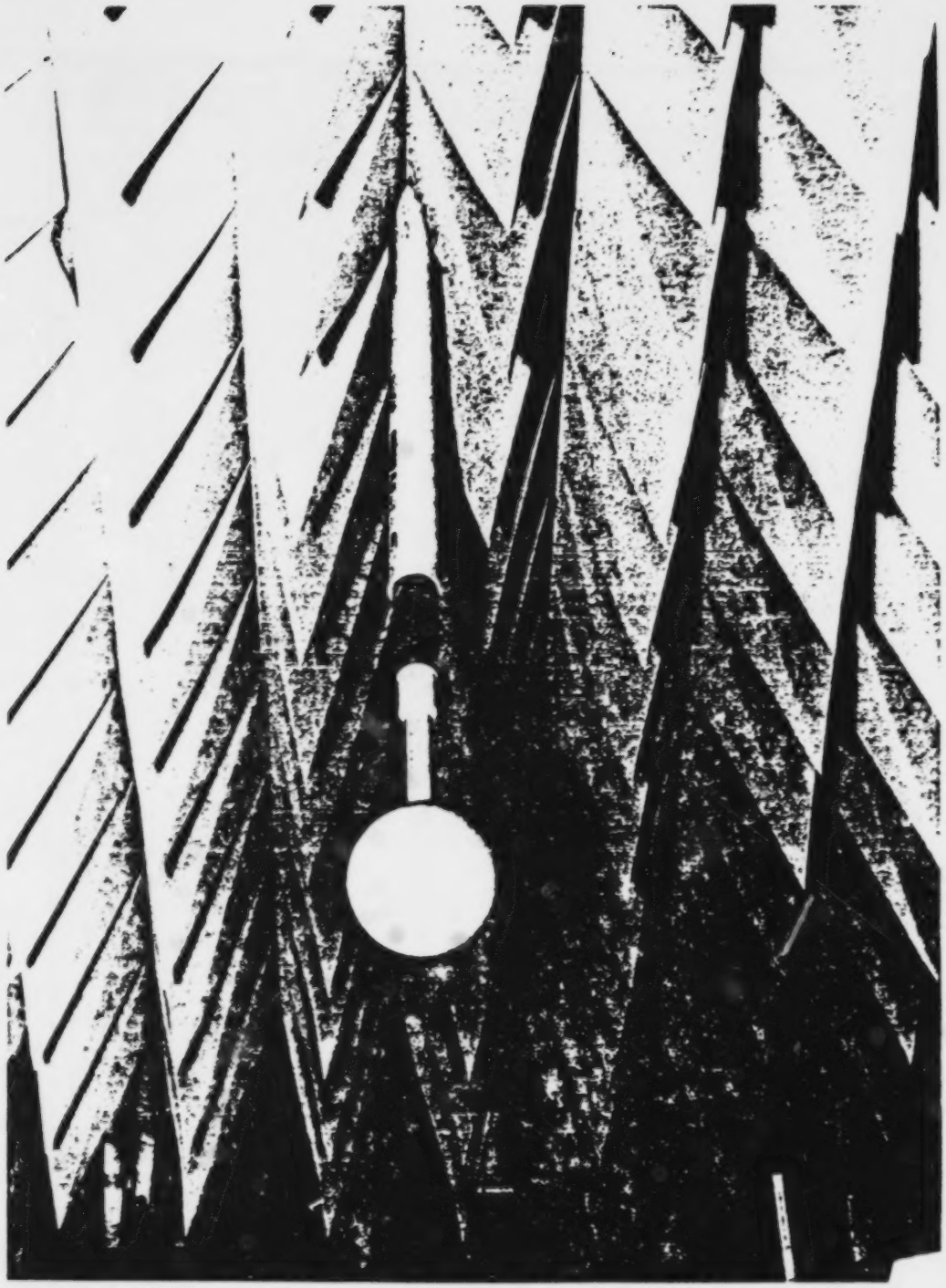

Figure 6. Picture showing the anechoic material.

variations in the field intensity as seen by the measurement probe. In this case the absolute calibration of the probe is unimportant because it is simply being used as relative indicator of the degree of reflections caused by the anechoic walls. The overall system to evaluate the range reflections is shown in figure 7.

To facilitate the range reflection tests, three additional devices had to be designed, built, and incorporated into the system used to evaluate these reflections. The first of these devices was a nonconductive horn support that was capable of supporting up to 50 lbs. The second device was a support to mount the probe at a constant distance from the horn. This probe support was to be nonconductive and be made of material that was nonperturbing to the electromagnetic field. The third addition to the system was a circuit capable of outputting a voltage proportional to the distance that the range walls moved with respect to each other.

Wood was used to build the horn support. Figure 8 shows the dimensions of the support. Because no nails, screws, or bolts could be used, wooden dowls and wood glue were used to attach the support members together. The platform of the support is variable in height and in angle to accomodate the different sized horns. A cushion pad was connected to the platform in order to increase the friction between the horn and the support such that slipping of the horn would be eliminated. This support can move independent or dependent of the anechoic wall thus allowing a maximum flexibility in its use.

The probe support was constructed from styrofoam. Styrofoam is a material that has little effect on electromagnetic fields. Figure 9 shows the

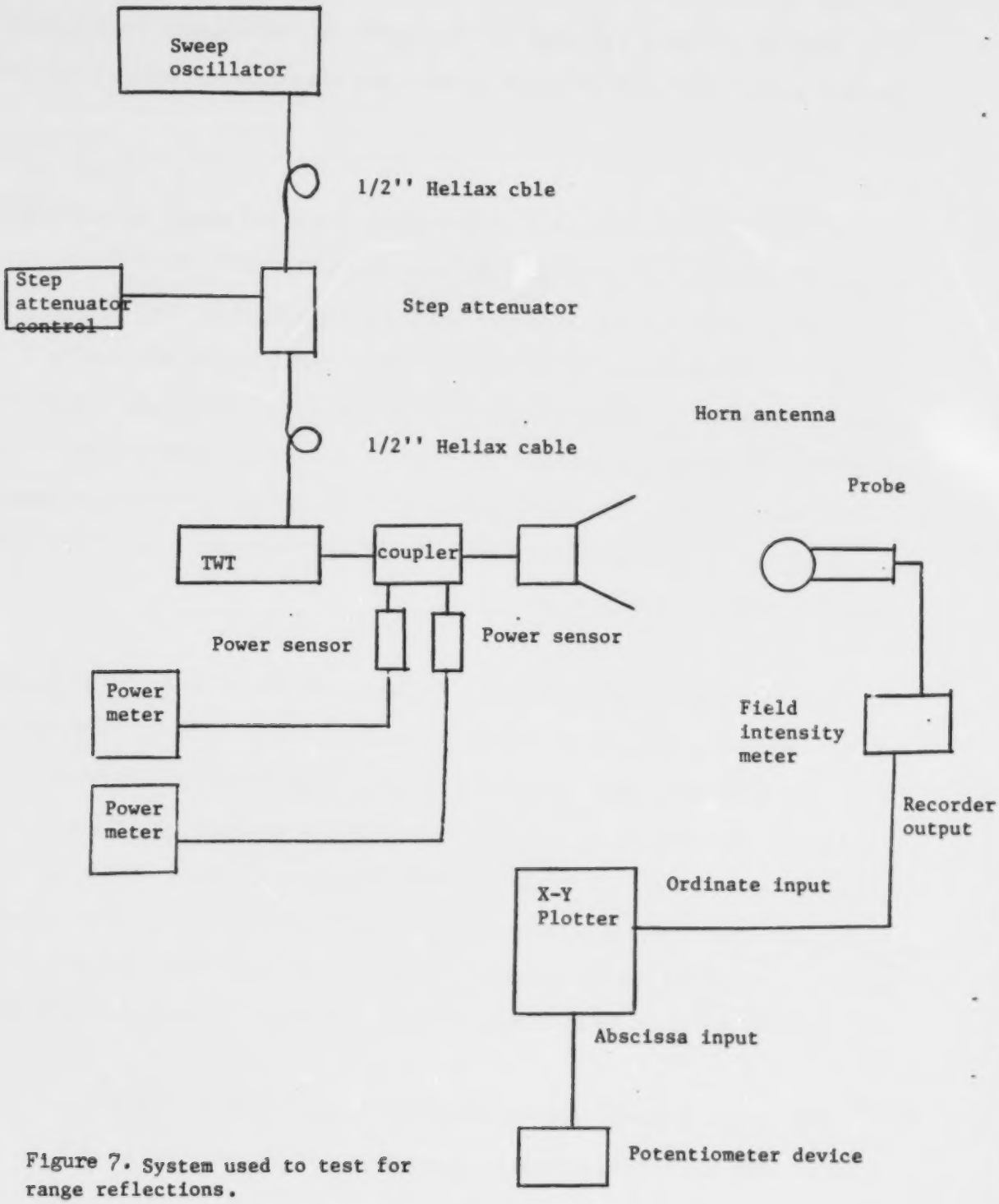

Figure 7. System used to test for range reflections.

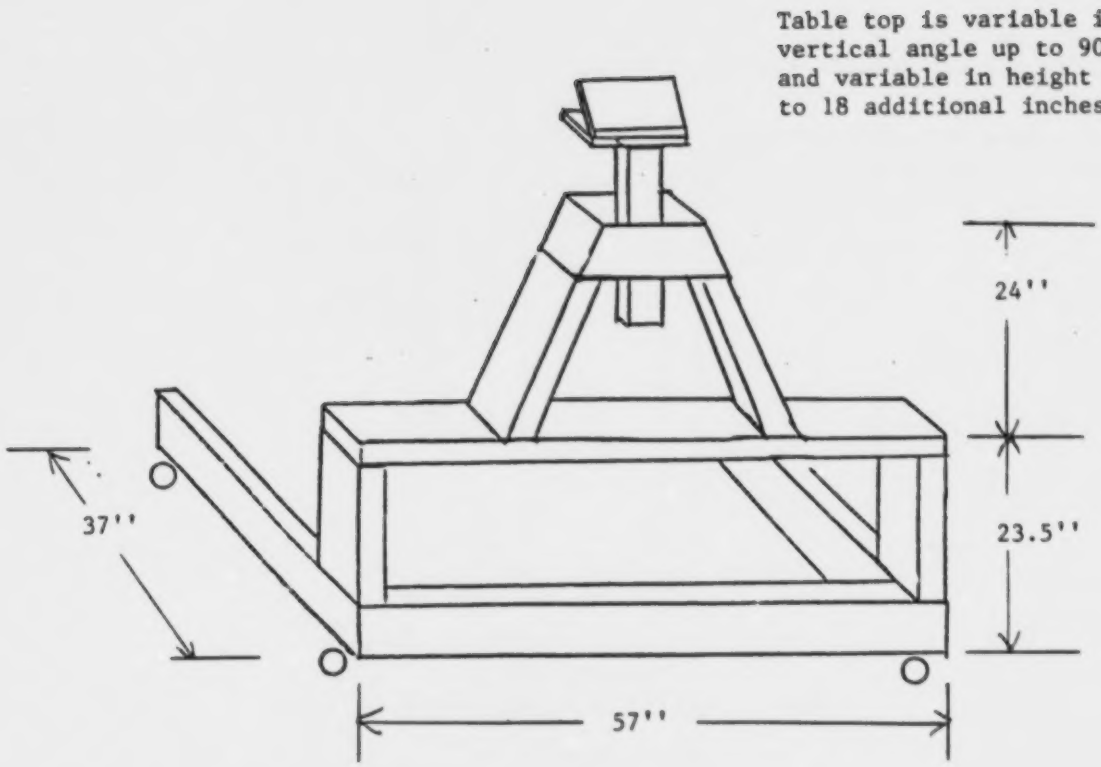

Figure 8. Sketch of horn support used in overall system showing key dimensions

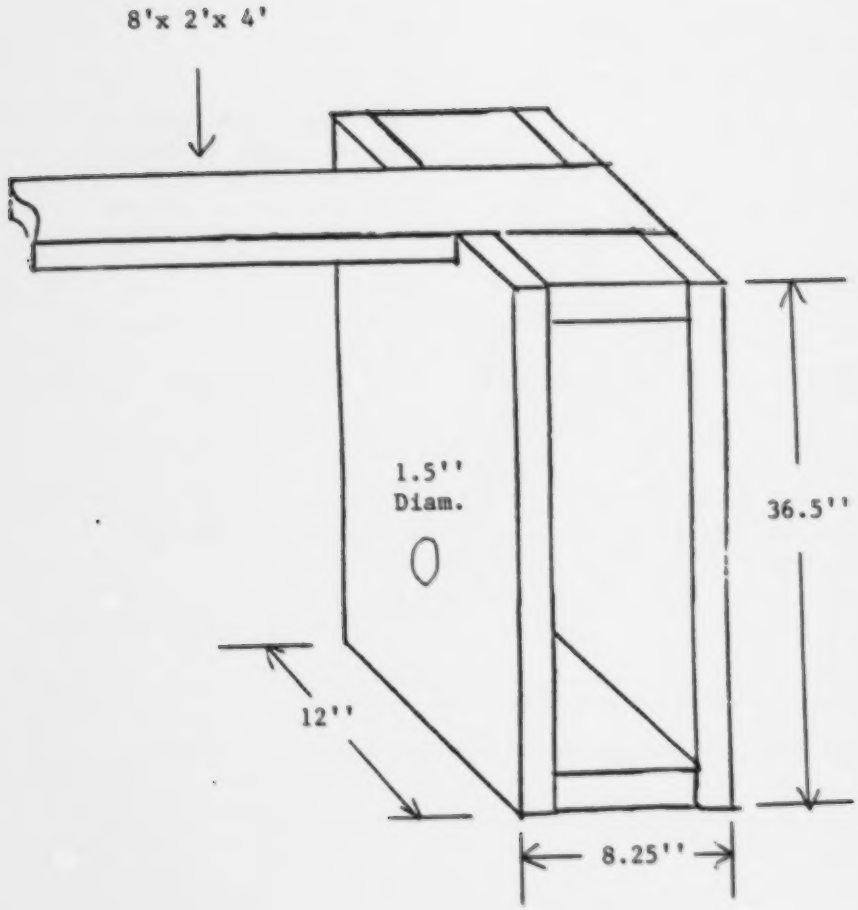

Figure 9. Styrafoam probe support used in reflection test system

probe support. The styrafoam housing was mounted on a 2 X 4 by which it could be attached to the range and thus be held a constant distance from the horn.

The last addition to this system, besides all the necessary instrumentation, was a potentiometer based circuit that when moved along the floor output DC voltages that were proportional to the distance traveled. A circuit schematic is shown in Figure 10. A wooden wheel was mounted right on the shaft of the potentiometer. When this wheel was rolled along the floor the resistor divider changed, thus changing the output voltage. A simple AC to DC power supply was used to supply the necessary voltage to the circuit. Figure 11 is a picture of the device. Figure 12 shows a graph of the output voltage versus the distance traveled. This circuit is to be used to produce voltage for the abscissa coordinate of an X-Y plotter which is shown in Figure 13.

The following procedure was followed when obtaining data from the range reflection tests:

1. Set up the system as shown in Figure 7.

2. Adjust the output level of the sweep oscillator until approximately 10 mW/cm^2 of power density exists at the probe.

3. Using a motor drive or pulling the wall by hand, move the walls with respect to each other. Care should be taken to move the walls as slow and constant as possible. The system used to perform the motor drive is shown in Figure 14.

4. Repeat this procedure for as many frequencies as is desired.

As will be observed the most severe reflections occur at lower frequencies. The reason for this is that the anechoic material is a more efficient nonreflector at higher frequencies than at lower frequencies. Appendix B contains the specifications of the AAP-18 anechoic material that was used in this project as well as the data that was obtained from the range reflection tests. Figure 15 is a graph of the results obtained from the experimental evaluation of the range reflections. The equations used to derive the errors are:

$$10 \log (S_{max}/S_{mean}) = + \text{ dB error} \quad (15)$$

$$10 \log (S_{min}/S_{mean}) = - \text{ dB error} \quad (16)$$

where:

S_{mean} = Mean value of field intensity, mW/cm^2,

S_{max} = Maximum deviation from the mean, mW/cm^2,

S_{min} = Minimum deviation from the mean, mW/cm^2.

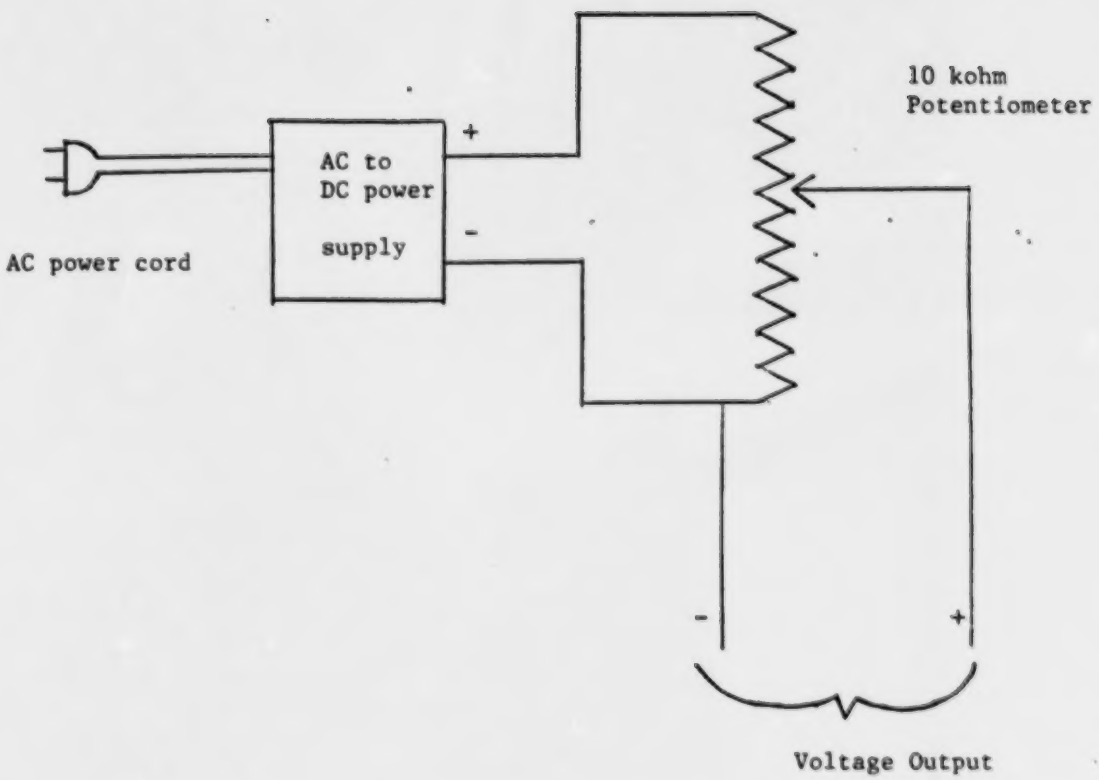

Figure 10. Simple potentiometer circuit used in reflection test system

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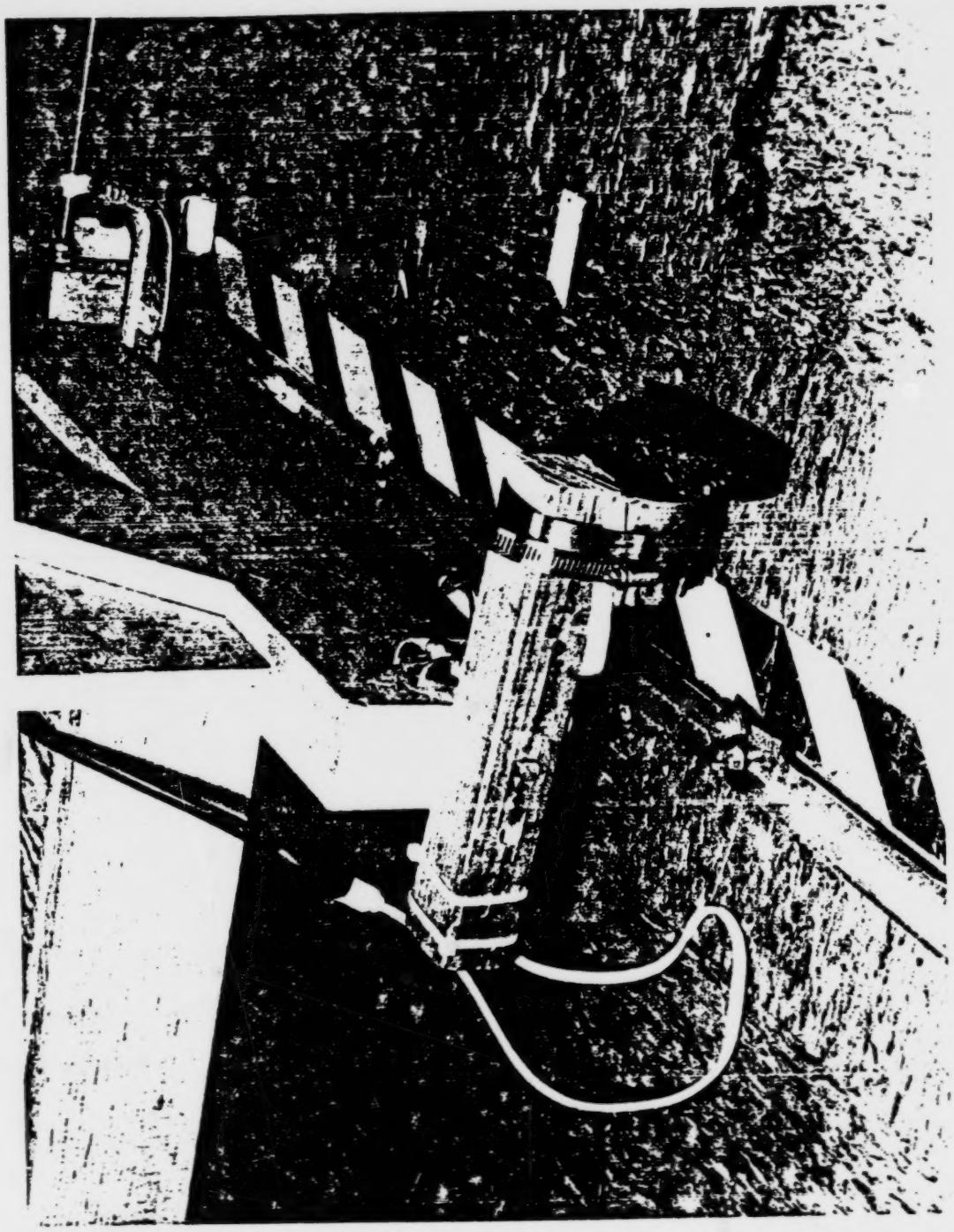

Figure 11. Picture of the potentiometer based circuit used to help plot distance in the reflection tests

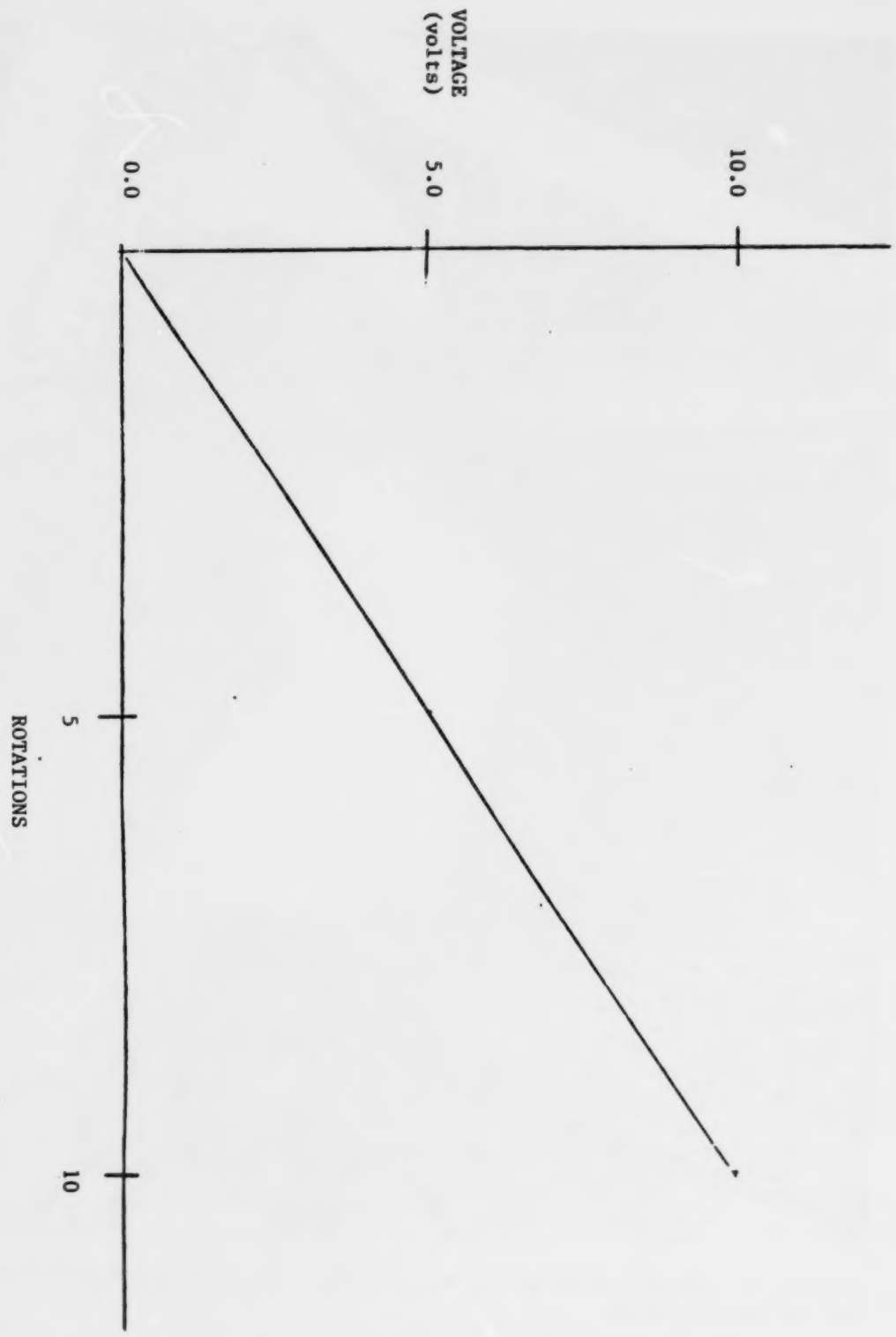

Figure 12. Plot of output voltage of potentiometer circuit

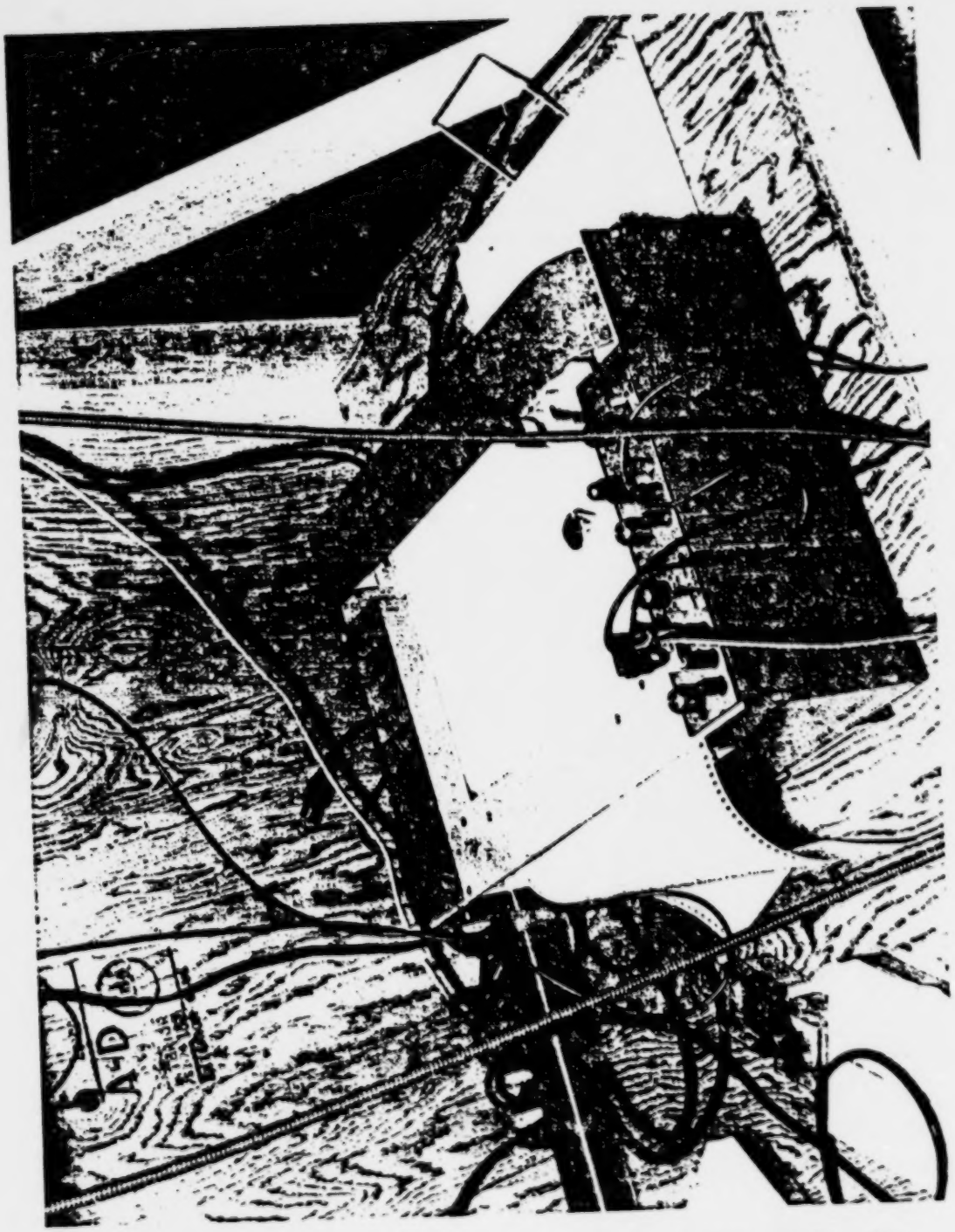

Figure 13. Picture showing the x-y plotter used to plot results from the reflection tests

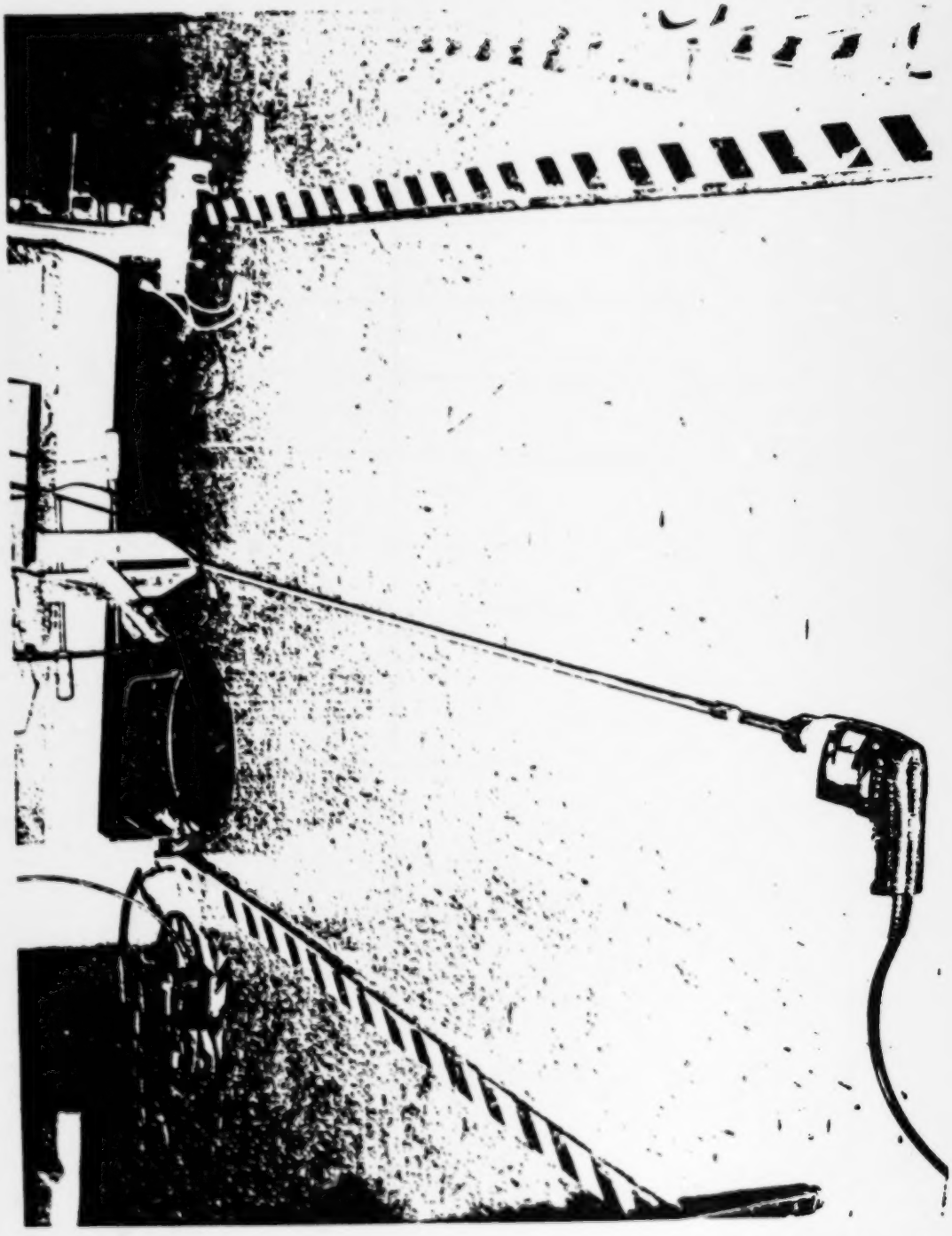

Figure 14. Picture showing drill arrangement used to push and pull the front wall during the reflection tests

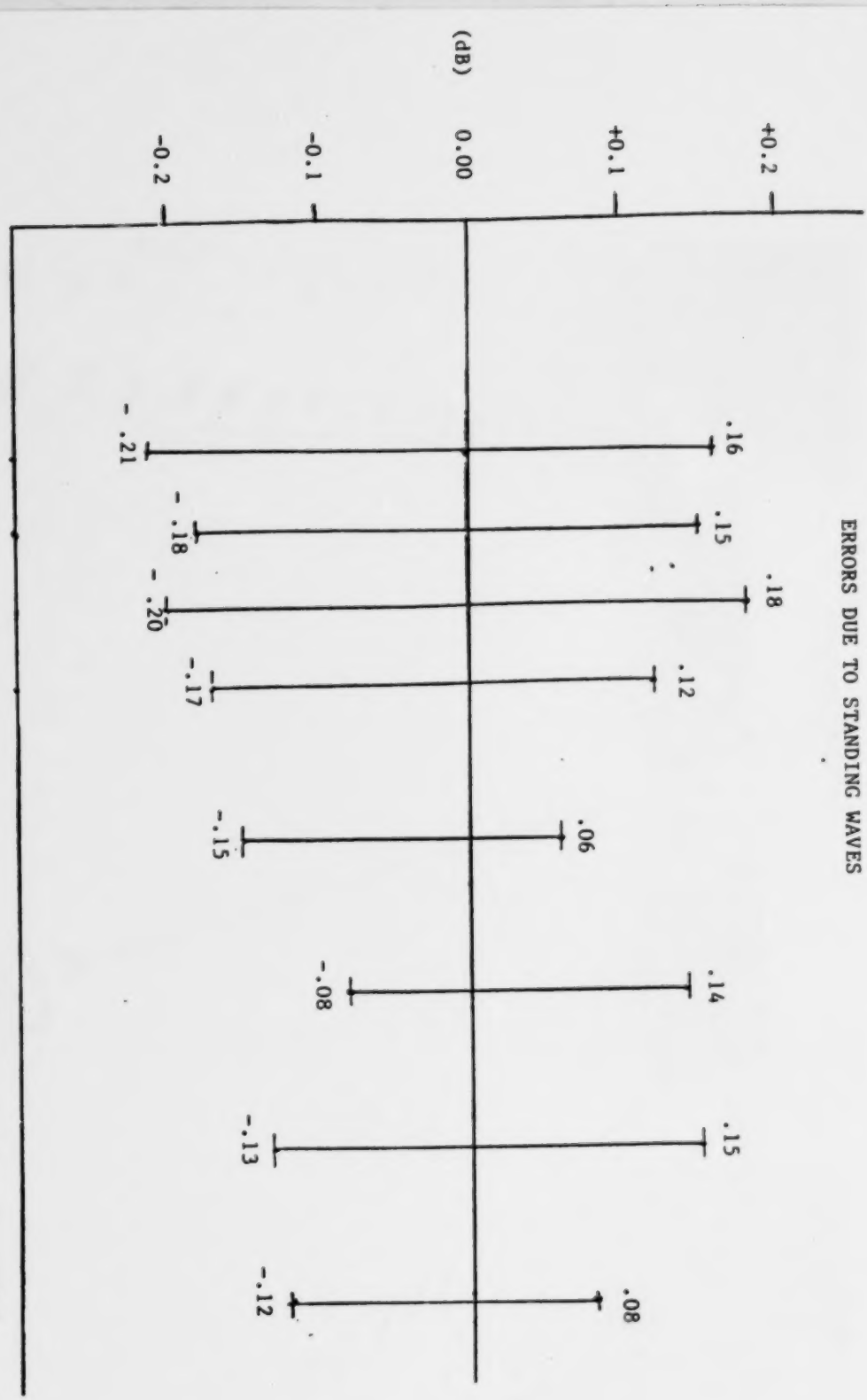

Figure 15. Results of range reflection tests

OPERATING CRITERION

The basic operating criteria are crucial to the successful operation of the calibration range. The four criteria to be concerned about are the horn arrangement, the probe orientation, the distance from horn to probe, and the power capabilities. Each one of these aspects will be examined separately and then an overall set of criterion will be arrived at.

The horn arrangement is a crucial factor. If the probe is emersed in the field out of the main beam, the results will be erroneous. It is of extreme importance that the probe is placed, as accurately as possible, on axis with the horn antenna. Equation 1 will not apply if this criterion is not met.

A way to proceed in meeting this criterion is to first set up the horn and probe by visual inspection. Then, being as accurate as possible, adjust the height to the center of the aperture of the horn antenna to match that of the height to the center of the probe. Use a level to adjust the vertical levelness of the horn. Last, adjust the horizontal angle of the horn such that it is directed precisely on line with the probe. An easy way to adjust the horizontal angle is to generate a small power density at the probe and then adjust the horizontal angle by moving the horn until a maximum power is received by the probe.

The second crucial factor is the probe orientation. Probe orientation in this text refers to the distance from the back wall to the probe. As was discussed in the range reflection section of this report, range reflections

introduce certain errors in accurately knowing the field intensity. Because testing was used to determine how severe these reflections are these errors can be incorporated into the maximum allowable error for the entire system. The ideal situation as far as eliminating these reflections is to have the back wall at an infinite distance from the probe. Physical and real limitations tell us that this is not possible. A set distance will be arrived at in the overall criterion.

The third criterion to be met is the distance from the horn to the probe. Here, as in range reflections, it would be ideal to place the probe at some infinite distance from the horn aperture. This would put the probe in the far field and the errors concerning the gain calculation would be neglegable. Once again, real and physical limitations do not allow this. To keep the gain calculation errors below 0.3 dB the probe will have to be placed at least 3 wavelengths away from the horn. This will be the initial criterion for this possible error.

The last crucial factor to be concerned about is the net power capabilities. The traveling wave tube (TWT) amplifiers used in this project are typically capable of outputting as low as 21 watts, and as high as 44 watts. Because the field intensity approximately follows the $1/d^2$ proportionality rule, it is not possible for very intense fields to be generated at large distances.

Typically fields as intense as 10 mW/cm^2 will need to be generated. If a typical gain of 30 and a distance of 1 meter is used, 42 watts would be required to generate that intense of a field. This is near the maximum output of the TWT. The worst case in this project is the low frequency end.

At 2 GHz the wavelength is 15 cm. To comply with the third criterion the calibration will have to be done at least 45 centimeters away from the horn. The power required to produce a 10 mW/cm^2 intensity would be about 10 watts. This is well within the limits of the TWT.

Knowing this, the criterion decided at is that the probe calibration begin 4 wavelengths from the aperture of the horn antenna. The probe should be placed at 40 to 45 centimeters from the back wall. This will introduce an error of about .45 dB to the calibration. The determination of one set of distances for all the frequency bands is desirable. to meet this desirability, the distance from the aperture of the horn to center of the probe would be 50 centimeters. This should make it possible to generate the desired fields over the entire 2 to 12.4 GHz frequency range.

COMPUTER CONTROL

Manually controlled calibration would be a lengthy and tedious project. A computer controller will then be enlisted to facilitate ease and speed of the calibration process. The HP Model 9845B computer will be employed to perform five major functions in the calibration process. The first function for the computer to perform is the calculation of horn gain and the calculation of the net power to be transmitted to the horn to produce the desired field intensity. Phase locking the frequency will be the computers second function. The third function to be performed will be to set the power that is to be transmitted to the horn. The fourth function will be to rotate the probe and make measurements off the field intensity as derived from the BRM. The last function will then be to convert the values taken during the rotation for plotting the dB error of the probe. Each of these functions will be examined individually.

Calculation of the horn gain will be done exactly as it was done in the discussion of standard gain horns in this report. Equations 2, 3, 4, 5, and 6 will be used to perform calculation of the horn gains. The net power will then be calculated using equation 1 and the gain that is determined by equation 6. The program will then determine, using the calibrating factors for the coupling devices and attenuators that are predetermined, how much power in dB that the forward and reflected power meters must read for the appropriate field to be generated.

The next function for the computer to perform is to phase lock the frequency. The computer will determine exactly what frequency should be

generated by the HP Model 8660B synthesized signal generator that is to be transmitted to the HP Model 8709A sychronizer to produce the desired harmonic frequency by which the desired output frequency is to be locked. Figures 16 and 17 show pictures of the HP Model 8660B and HP Model 8709A. The harmonic signal that is produced is then input to the phase lock connector on the back of the HP Model 8620C sweep oscillator. This will then lock the output frequency such that no drifting occurs which may cause different RF levels. The HP Model 8620C is also told, by the computer via the IEEE 488 interface bus, what the output frequency is.

Now the computer has to set the output power. This can be a real problem because the RF level on the HP Model 8620C is not controllable through the IEEE 488 interface bus. The technique I will use to perform this function is to use two different types of attenuators to control the power that is input to the TWT. A picture showing the three TWT's to be used in the project can be seen in Figure 18. The course adjustment will be done with the use of a 10 dB step attenuator, and the fine adjustment will be done through the use of a pin modulator which has been set to vary from approximately 0 dB to 15 dB. Because the pin modulators are not very wide band instruments, three different pin modulators will have to be used depending on frequency. The pin modulators are a current controlled device so an additional buffer type of amplifier had to be designed.

After some experimentation, it was determined that controlling the voltage supplied to the control port of the pin modulators works well enough for the purpose of controlling the attenuation. Figure 19 is a circuit schematic of the amplifier that was designed for this purpose. Figure 20 is a picture of the actual unit that was built for this purpose.

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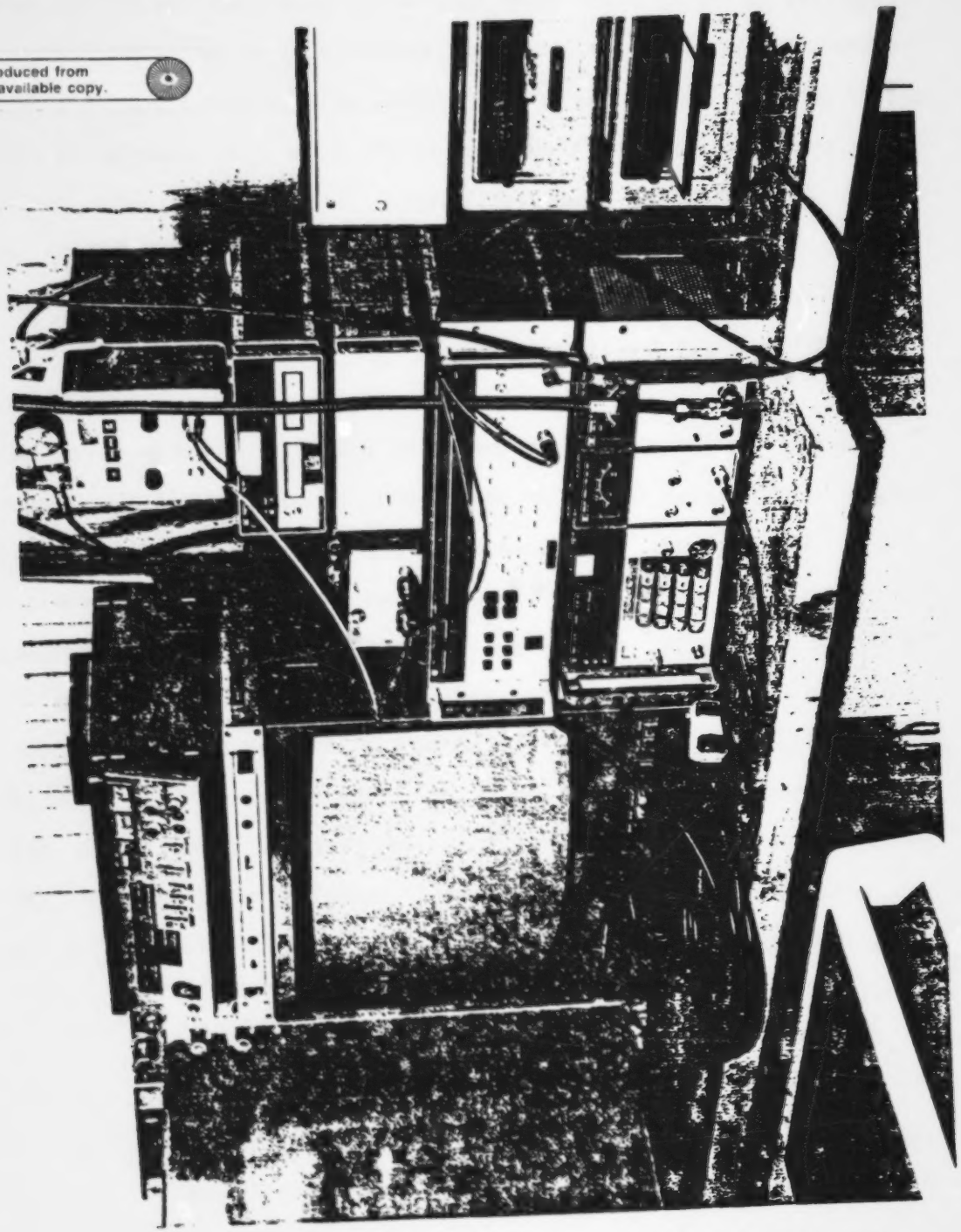

Figure 16. Picture showing signal generator used to phase lock frequency HP model 8660B located in bottom center

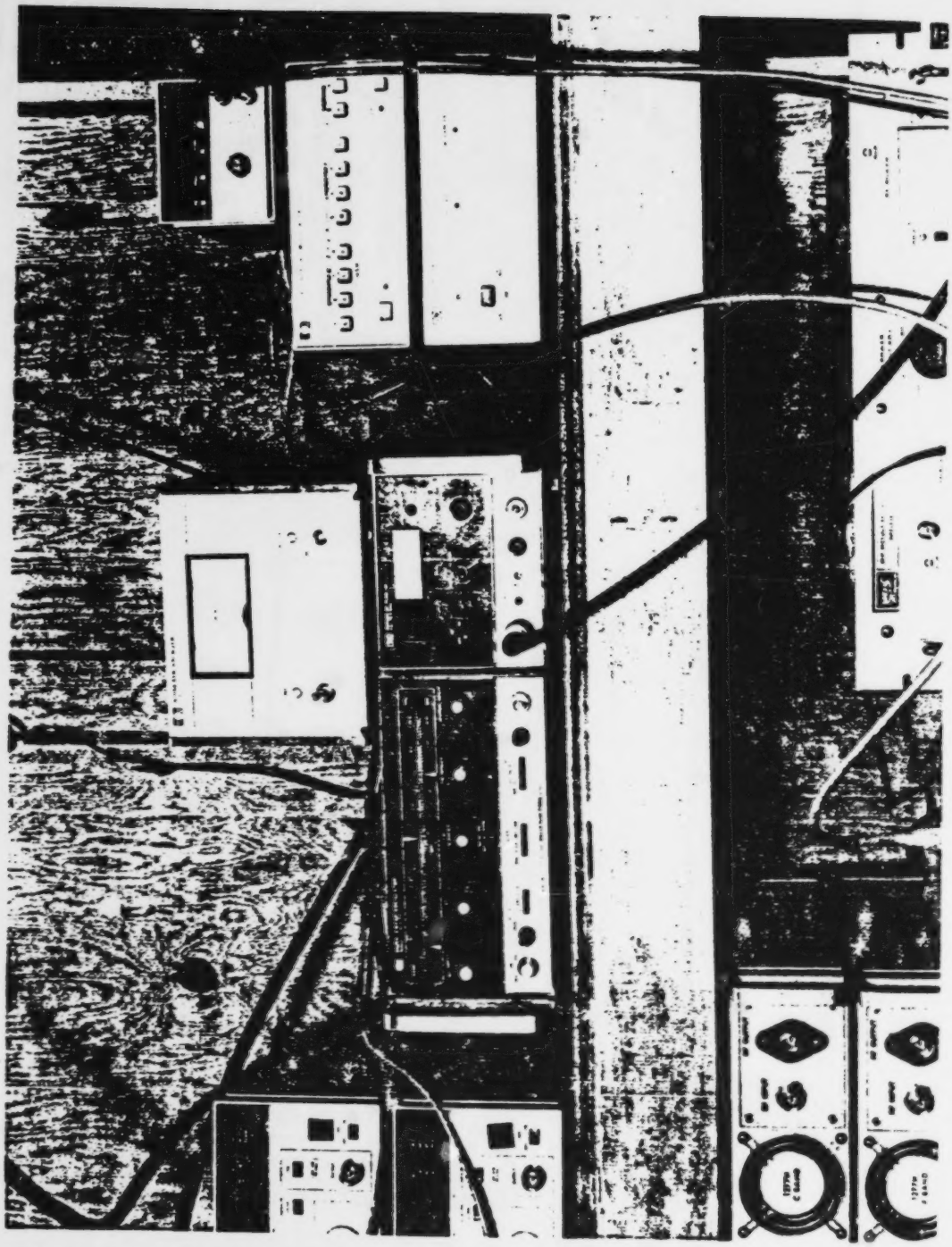

Figure 17. HP model 8709A located at the top center

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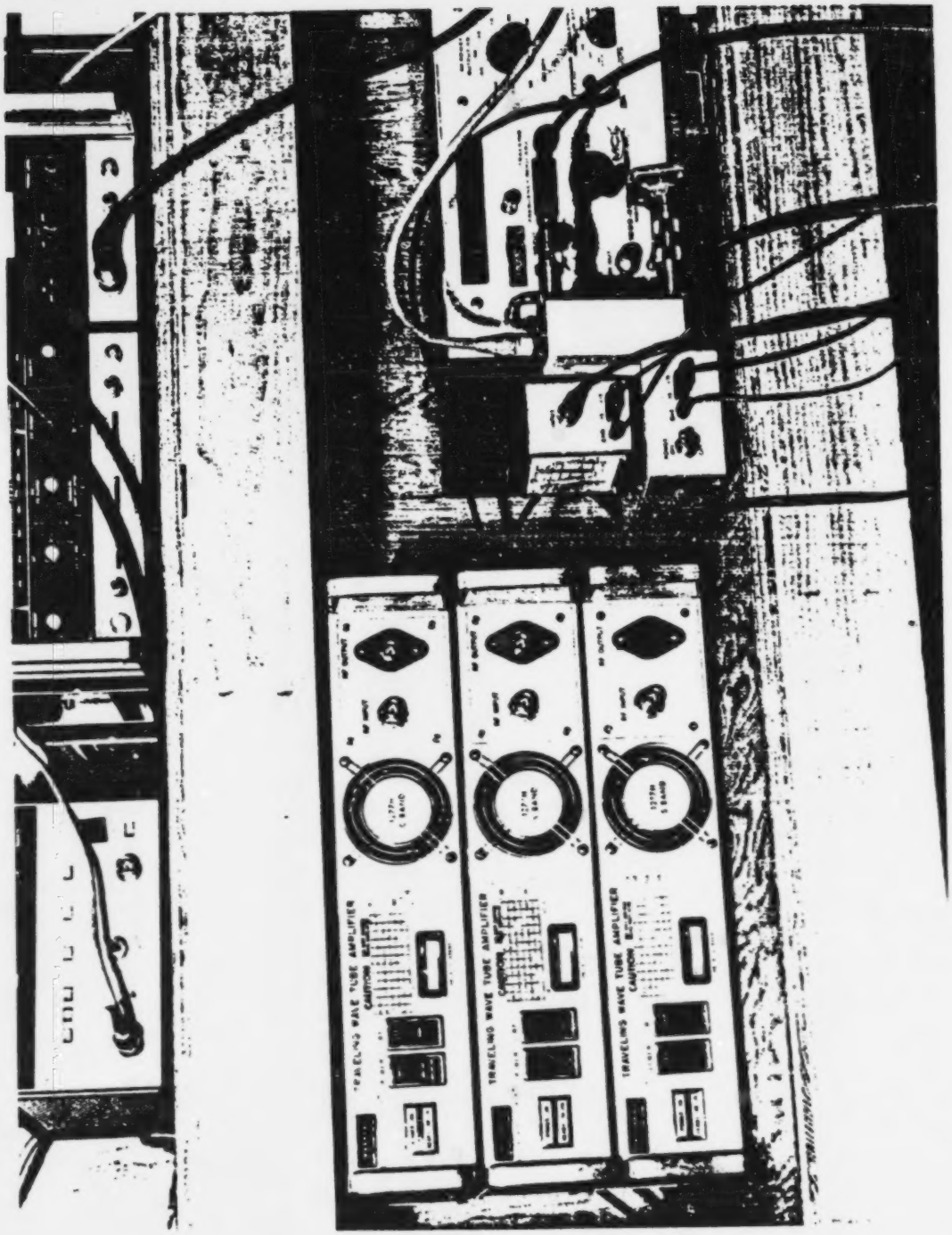

Figure 18. Picture showing the series of TWTs used in this project

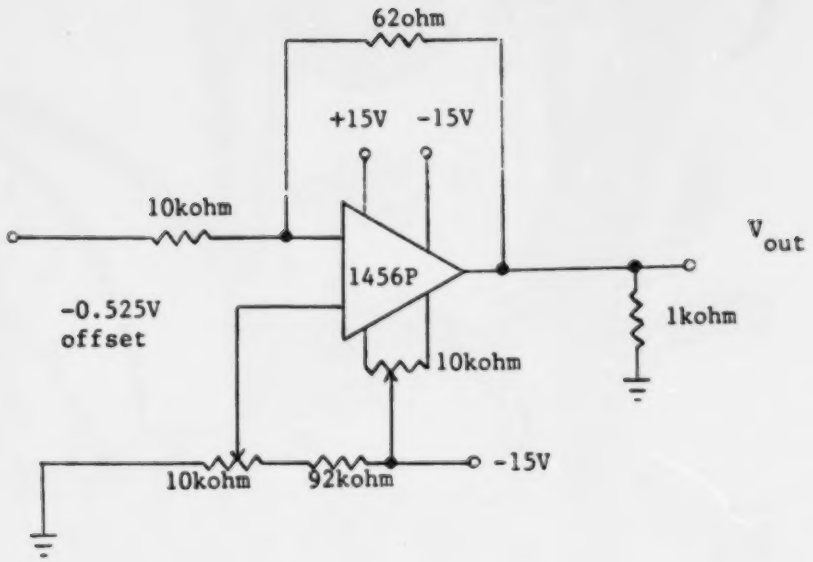

Figure 19. Circuit schematic of buffer amplifier used to control the pin modulators

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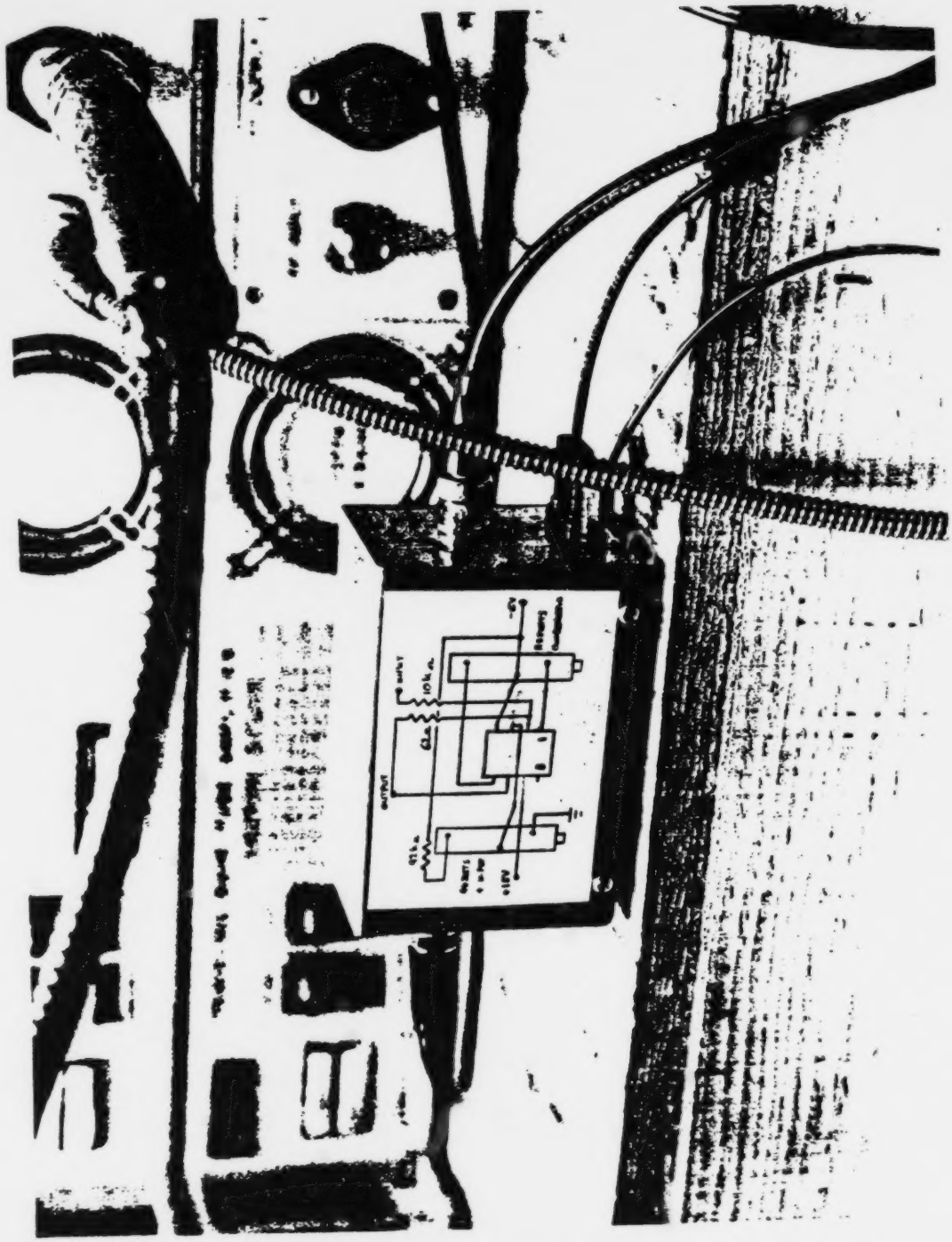

Figure 20. Picture of actual buffer amplifier used to control the pin modulators

The HP Model 9845B computer shown in Figure 21 begins the power setting routine by making an intelligent guess, as specified by the program, as to what values the step attenuator and pin modulator are to have. The step attenuator used is an HP Model 8495H attenuator with an HP Model 11713A attenuator driver. The HP Model 11713A is an IEEE 488 controllable unit. The three different pin modulators to be used are listed in Table 1. The buffer amplifier, which controls the pin modulators, is controlled by an HP Model 59303A digital to analog converter. All of the units previously named can be seen in Figure 22. As the adjustments in attenuation are made, the computer continually makes measurements of the power meters connected to the forward and reflected ports of the coupler. The power meters used are HP Model 436A power meters with HP Model 8481A power sensors. A binary search algorithm is used by the computer to tell whether the proper power readings are obtained to produce the desired field intensity. The computer must change the attenuators back and forth to adjust the proper power input to the TWT. During the first attempt to set the power the mismatch is calculated so that the computer can determine how much the power must be increased due to the fact that reflections occur at the horn antenna. When the desired power is finally set, the computer locks the values needed controlling the attenuator driver and the digital to analog converter. These are the two units that ultimately control the attenuators which in turn control the power to the TWT which in turn controls the power that is delivered to the horn antenna.

Rotating the probe in the field is the next important step. A HAM model IV rotator is used to perform this function. See Figure 23. The rotator control is switched on and off by the use of an HP Model 59306A relay

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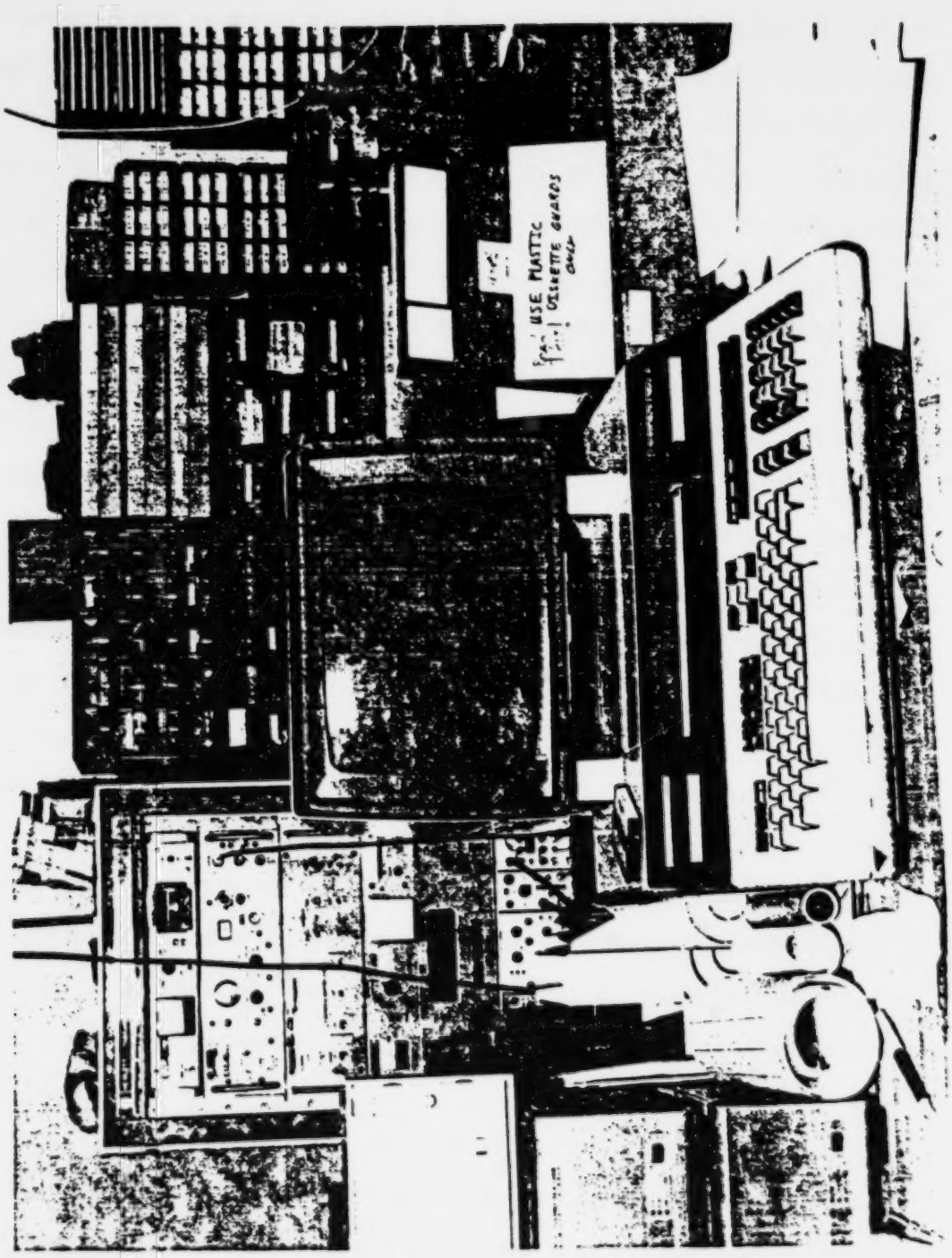

Figure 21. Picture of HP model 9845B computer used as controller

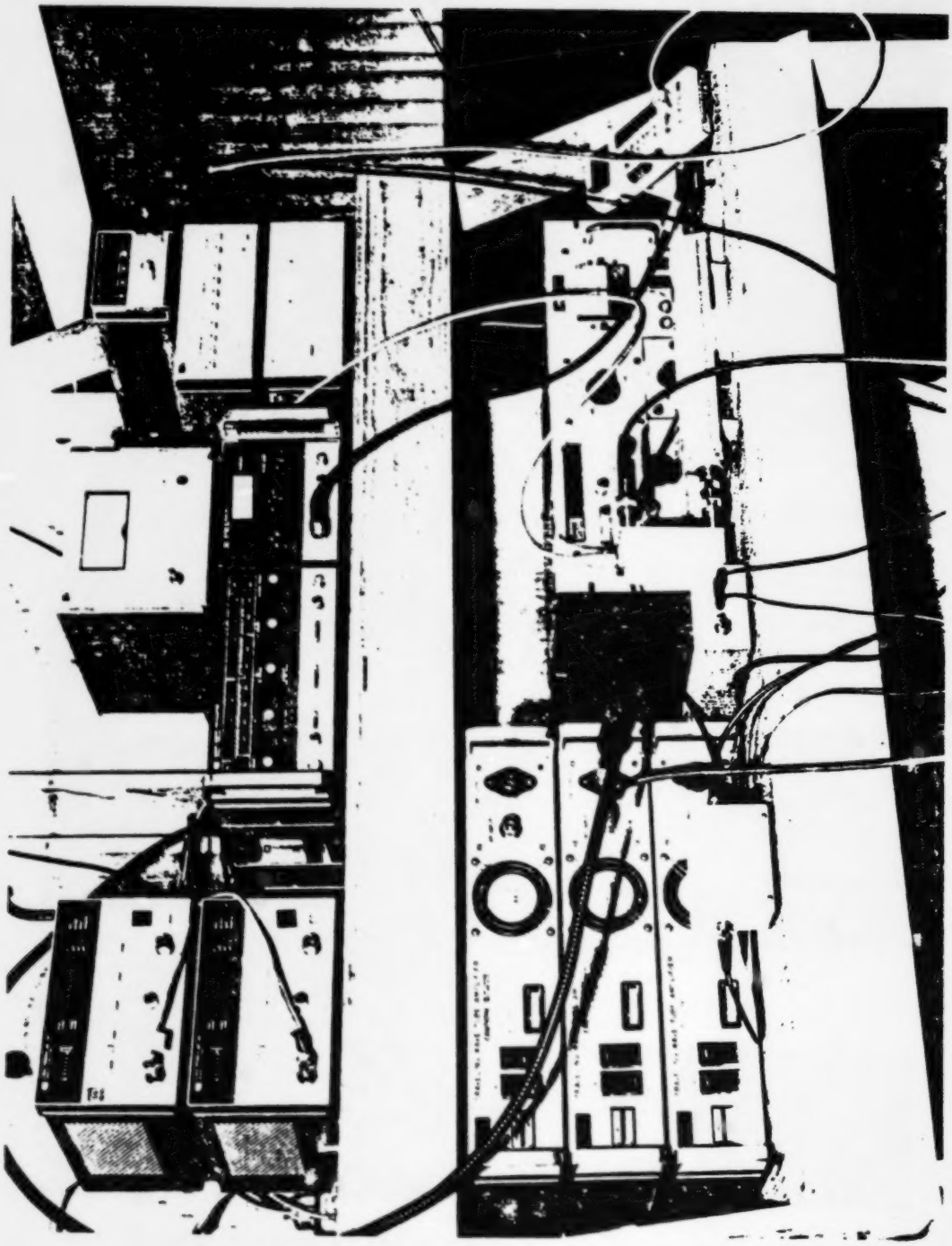

Figure 22. Hp model 8495 step attenuator located at bottom center HP model 11713A attenuator driver located second from the top right hand corner, HP model 59303A digital to analog converter located at the top right hand corner, Two HP model 436A power meters located at the top left hand corner

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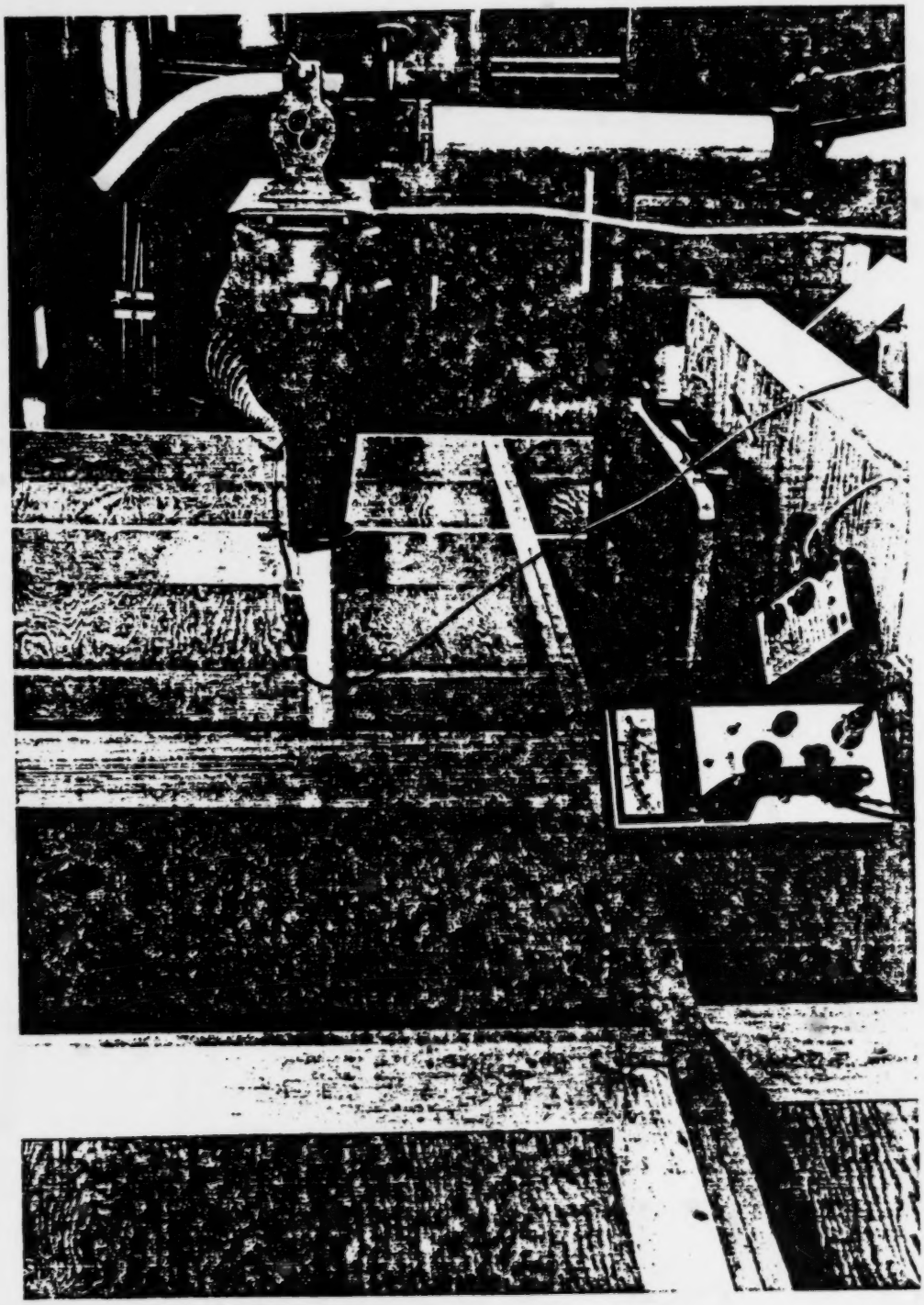

Figure 23. Picture showing the HAM model IV rotator used to rotate the probe

actuator. The relay actuator is an IEEE 488 controllable unit. Because the rotator control is always on during operation, it needs merely to be switched on and off by the relay actuator to initiate a rotation. The first rotation of the probe always starts in the clockwise direction. Each successive rotation then is made in an alternating fashion. The angle of rotation is a full 360^{o}. During this rotation approximately 600 measurements of the field intensity are made.

Measurements of the field intensity are made with the use of an HP Model 59313A analog to digital converter. Figure 24 shows a picture of the relay actuator, the analog to digital converter, and the rotator control. The selected dynamic range of the input to the channel that is being used is 0.0 to 3.5 volts. This channel is fed by the recorder output of the BRM that is being calibrated. A conversion is then made so that the computer can determine what field intensity the probe appears to sense. This approach also yields data which can be examined for the isotropicity characteristics of the probe.

Now that the data has all been collected the computer then coverts the data obtained and determines the dB error of the probe. These results are output as dB error plots of individual frequencies, tables of dB errors, and a summary plot of dB errors for all the frequencies that were done.

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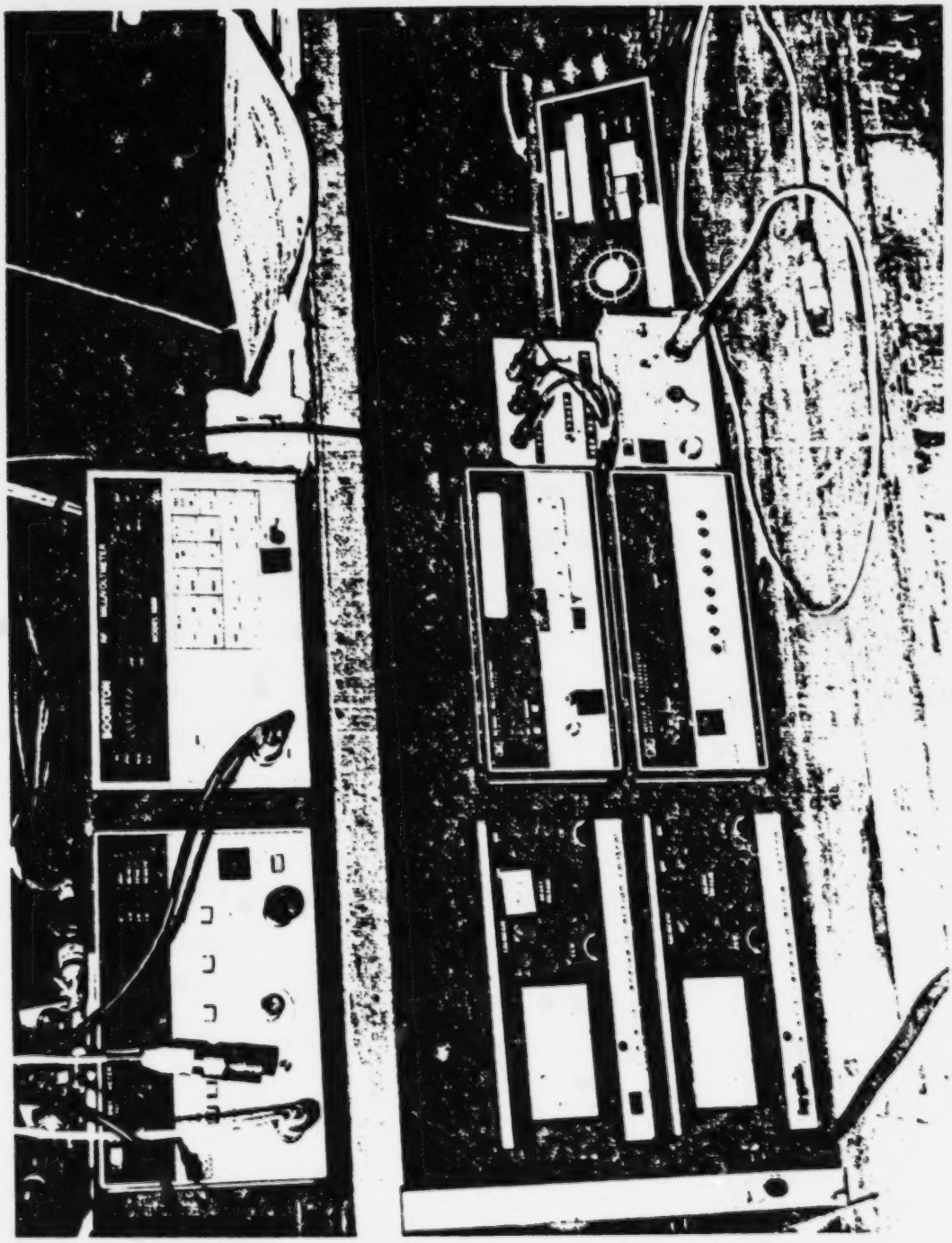

Figure 24. Picture showing HP model 59306A relay actuator (middle center), HP model 59313A analog to digital converter (bottom center), and CDE rotator control (middle lefthand side)

OVERALL SYSTEM AND OPERATION

The overall system can be seen in Figure 25. Those devices which have asterisks next to them have to be changed depending upon what frequency band is to be used. Table 1 is a table of the five frequency bands and the appropriate devices to be used corresponding to those frequency bands. When running the system care has to be taken to align the probe and horn properly. Figure 2 is a picture of one such alignment. All of the necessary equipment must be turned on. Then, the operator merely runs the "Horngo" program and answers the questions that are asked by the computer. A listing of the program as well as some illustrative runs are shown in Appendix C.

As can be seen in a typical run, the computer outputs much information dealing with the calibration. Along with listing the probe and BRM used it also shows what field intensity that was set. The first plots that are output are plots of the measurements made during a rotation. The first table that is output is a table of the frequencies, the average power read by the BRM, the highest value read by the BRM, the lowest value read by the BRM, and the high-low error. The second table output by the computer is a list of the preset errors and the post power errors due to drift at the corresponding frequencies. The last plot output by the computer is a plot of the overall errors, in dB, of the frequency band that the calibration was done at. This last plot is referred to as a summary plot.

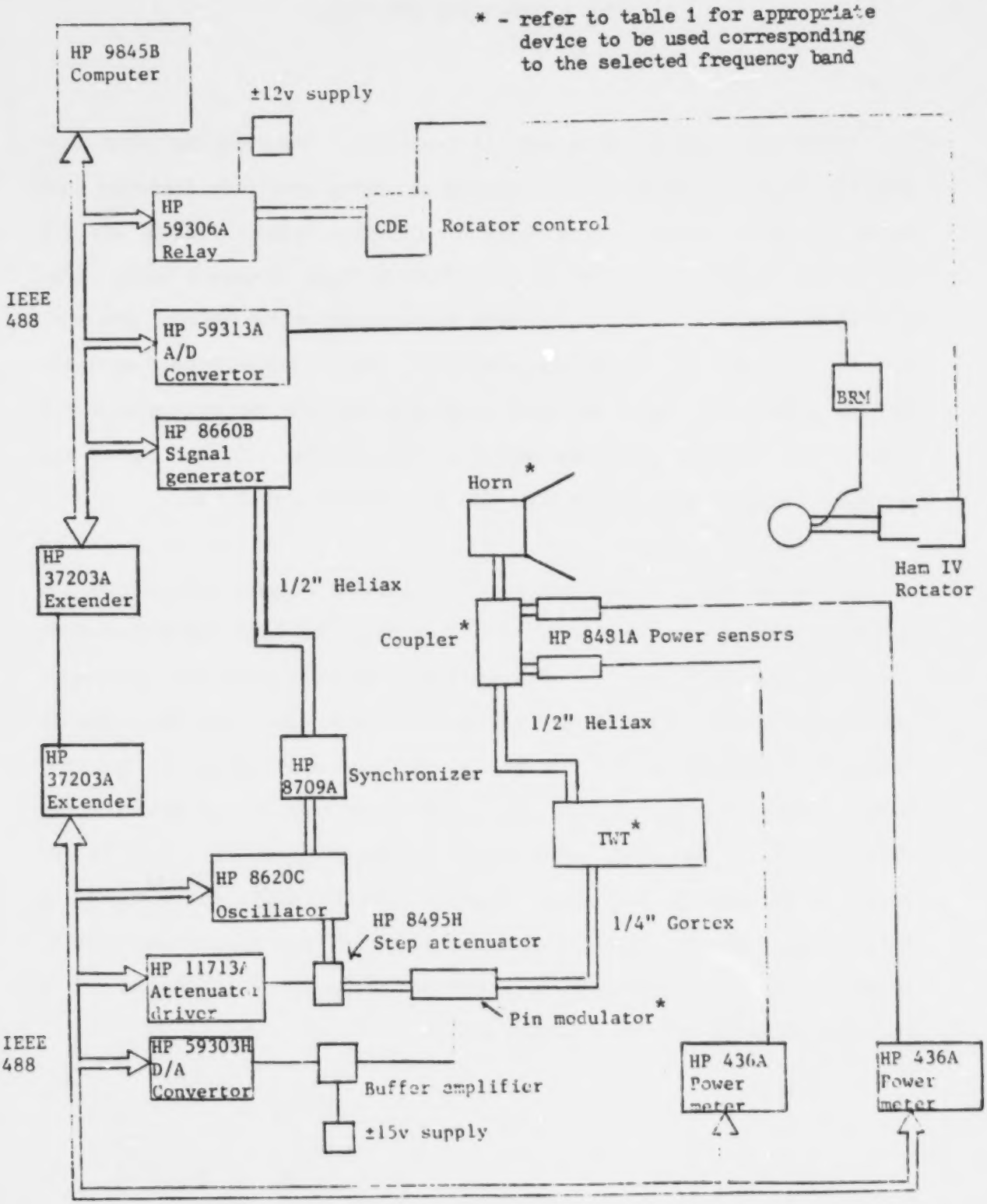

Figure 25. Block diagram of general overall system

Table 1. List of appropriate equipment for corresponding frequency bands

FREQUENCY (GHz)	EQUIPMENT
2.0 - 2.6	TWT - Hughes model 1277H S Band Coupler - Narda model 3022 bidirectional coupler with Narda 10dB attenuator on forward port S/N 03508 Antenna - Narda model 645 standard gain horn Pin Modulator - HP model 8732B pin modulator
2.6 - 3.95	TWT - Hughes model 1277H S Band Coupler - Narda model 3022 bidirectional coupler with Narda 10dB attenuator on forward port S/N 03508 Antenna - Narda model 644 standard gain horn Pin Modulator - HP model 8732B pin modulator
3.95 - 5.50	TWT - Hughes model 1277H C Band Coupler - Narda model 3024 bidirectional coupler with Narda 10dB attenuator on forward port S/N 03482 Antenna - Narda model 643 standard gain horn Pin Modulator - HP model 8733B pin modulator
5.50 - 8.2	TWT - Hughes model 1277H C Band Coupler - Narda model 3024 bidirectional coupler with Narda 10dB attenuator on forward port S/N 03482 Antenna - Narda model 642 standard gain horn Pin Modulator - HP model 8733B pin modulator

Table 1. List of appropriate equipment for corresponding frequency bands

FREQUENCY (GHz)	EQUIPMENT
8.2 - 12.4	TWT - Hughes model 1277H X Band Coupler - Two Narda model 3095 directional couplers connected in series with S/N 08232 as forward and with S/N 08233 as reflected Wienschel model 20dB attenuator on forward port S/N AE 9823 Narda model 10dB attenuator on reflected port S/N 03508 Antenna - Narda model 640 standard gain horn Pin Modulator - HP model 8734B pin modulator

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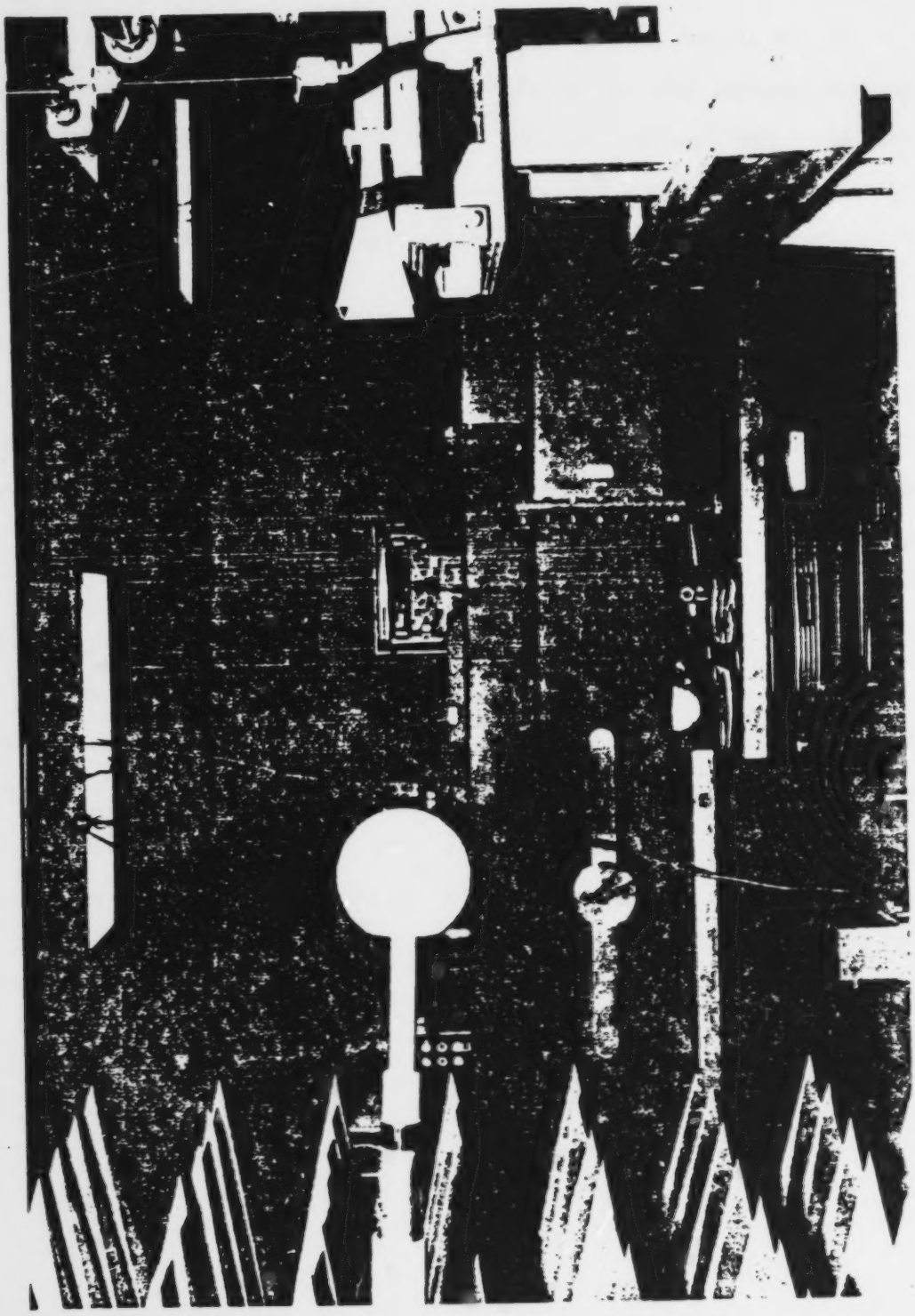


Figure 26. Picture showing typical horn probe arrangement

RECOMMENDATIONS AND CONCLUSIONS

As was stated in the beginning of this report, some of the devices used in this project need to be calibrated in order to build confidence in the results. The coupling devices and attenuators used to measure the power delivered to the horn need to be calibrated first. All other information given in this report will still apply as far as errors are concerned.

When performing the calibration, care must be taken to make sure that the criterion, stated in the operation criterion section of this report, is met. When horn arrangement, or probe orientation, or gain calculation, or power output capabilities do not carefully adhere to the criterion, erroneous results will be obtained from calibration test runs.

This procedure turns out to be a relatively good way to perform calibration of Broadband Radiation Monitors. The maximum errors in the overall system are ± 1.0 dB. In real life situations this is a reasonable error. These errors can be much worse if the procedures and criterion outlined in this report are not used. The same sequence of events documented in this report can be used to include frequencies as low as 1 GHz and as high as 40 GHz.

APPENDIX A

LISTING OF HORN GAIN PROGRAM

AND

TYPICAL HORN GAINS

```
10     OPTION BASE 1
20     PRINTER IS 7,1
30     OVERLAP
40     DIM Grat$[15]
50     SHORT Db(1500),Gain,Min_freq,Max_freq
60     EXIT GRAPHICS
70     Nhorn=8
80     DEG
90     INPUT "Enter the Horn you wish to analyze?",Horn
100    RESTORE
110    FOR I=1 TO Nhorn
120       READ Thorn,Al,Bl,Lh,Le,Min_freq,Max_freq
130       IF Horn=Thorn THEN 200
140    NEXT I
150    BEEP
160    DISP "Horn #";Horn;"not found."
170    RESTORE
180    WAIT 3000
190    GOTO 90
200    PRINT PAGE;"Dimensions for Horn #";Horn;LIN(1)
210    PRINT "      A =";Al;"     B =";Bl;"    Lh =";Lh;"    Le =";Le;LIN(1)
220    PRINT "           Frequency Range: ";Min_freq;"TO";Max_freq;"GHz"
230    INPUT "Enter the Start, Finish, and Increment Distances (Meters)?",Ds,Df,D
i
240    INPUT "Enter the Start, Finish, and Increment Frequencies in GHz?",Sf,Ff,I
f
250    PRINT LIN(1);"Gains will be Calculated Starting from";Ds;"to";Df;"in Steps
 of";Di
260    IF (Sf)=Min_freq) AND (Ff(=Max_freq) THEN 310
270    BEEP
280    DISP "Frequency out of the range for Horn #";Horn
290    WAIT 3000
300    GOTO 240
310    Bin=3
320    INPUT "Do you want to Print/Plot",Bin
330    Print=BIT(Bin,0)
340    Plot=BIT(Bin,1)
350    Z=35
360    C=3.0E10
370    FOR Freq=Sf TO Ff STEP If
380       K=1
381       Q=1
382       P=0
390       FOR J=Ds TO Df STEP Di
400       IF NOT Print THEN 480
410       IF (Q-1) MOD Z THEN 480
420       IF P THEN PRINT PAGE
430       PRINT LIN(1);"Frequency =";Freq;"GHz";LIN(2)
440       PRINT "    Distance      Gain       Gain Ratio"
450       PRINT "    (Meters)      (dB)";LIN(1)
460       P=P+1
461       Q=1
470       IF P=2 THEN Z=40
480          L=C/(Freq*1.0E9)
490          Ad=Al/L
500          Bd=Bl/L
510          Alh=Lh/L
520          D=J/L*100
530          Ale=Le/L
```

```
540         Alpha=Ad^2*(1/Alh+1/D)
550         Beta=Bd^2*(1/Ale+1/D)
560         Rh=.01*Alpha*(1+10.19*Alpha+.51*Alpha^2-.097*Alpha^3)
570         Re=.1*Beta^2*(2.31+.053*Beta)
580         Gain=10*LGT(Ad*Bd)+10.08-Rh-Re
590         Grat=10^(Gain/10)
600         IF Print THEN PRINT USING 610;J,Gain,Grat
610         IMAGE 4X,DDD.DD,7X,DD.DD,8X,DDD.DD
620         Db(K)=Gain
630         IF (FRACT(Q/5)=0) AND Print THEN PRINT
640         K=K+1
641         Q=Q+1
650      NEXT J
660   IF NOT Plot THEN 1070
670 Plot:    PLOTTER IS "9872A"
680   GRAPHICS
690   REDIM Db(K)
700   LOCATE 10,115,10,90
710   Ymax=20
720   Yinc=5
730   SCALE 0,Df,0,Ymax
740   Di1=Df/4
750   AXES Di1,Yinc,0,0
760   FRAME
770   K=1
780   LORG 5
790   FOR I=Ds TO Df STEP Di
800      PLOT I,Db(K)
810      K=K+1
820   NEXT I
822   CSIZE 3
830   FOR I=0 TO Df STEP Di1
840      MOVE I,-.8
850      LABEL USING "#,DZ.DD";I
860   NEXT I
870   LORG 8
880   Yc=(Ds-Df)*.02
890   FOR I=0 TO Ymax STEP Yinc
900      MOVE Yc,I
910      LABEL USING "#,MDD";I
920   NEXT I
940   LORG 5
950   CSIZE 4,8/15,15
960   MOVE Df/2,Ymax*1.10
970   LABEL USING "#,K";"GAIN PLOT FOR HORN #";Horn
980   CSIZE 3.3
990   MOVE Df/2,-2
1000  LABEL USING "#,K";"Distance (Meters)"
1010  MOVE Df/2,Ymax*1.05
1020  LABEL USING "#,K";"Frequency = ";Freq;" GHz"
1030  LDIR 90
1040  MOVE -Df*.08,Ymax/2
1050  LABEL USING "#,K";"Gain (dB)"
1060  REDIM Db(1500)
1070  NEXT Freq
1080  GOTO 60
1090  END
1100  !
1110  !                                                    Min        Max
1120  !    Horn #    A       B       Lh        Le        Freq       Freq
```

```
1130  !
1140  DATA  638,   3.73,   2.93,  6.90,     5.94,  18.00,     26.5
1150  DATA  639,   5.56,   4.28,  9.56,     9.26,  12.40,     18.0
1160  DATA  640,   7.35,   5.5,  13.094,   10.991,   8.20,     12.4
1170  DATA  642,  11.25,   8.3,  19.946,   17.448,   5.40,      8.2
1180  DATA  643,  15.25,  11.25, 27.731,   23.186,   3.95,      5.85
1190  DATA  644,  23.1,   17.2,  40.476,   34.914,   2.60,      3.95
1200  DATA  645,  35.1,   25.95, 62.122,   53.113,   1.70,      2.6
1210  DATA  646,  53.1,   39.25, 92.771,   79.947,   1.12,      1.7
1220  END
```

Dimensions for Horn # 645

A = 35.1 B = 25.95 Lh = 62.122 Le = 53.113

Frequency Range: 1.7 TO 2.6 GHz

Gains will be Calculated Starting from .15 to 1 in Steps of .01

Frequency = 2 GHz

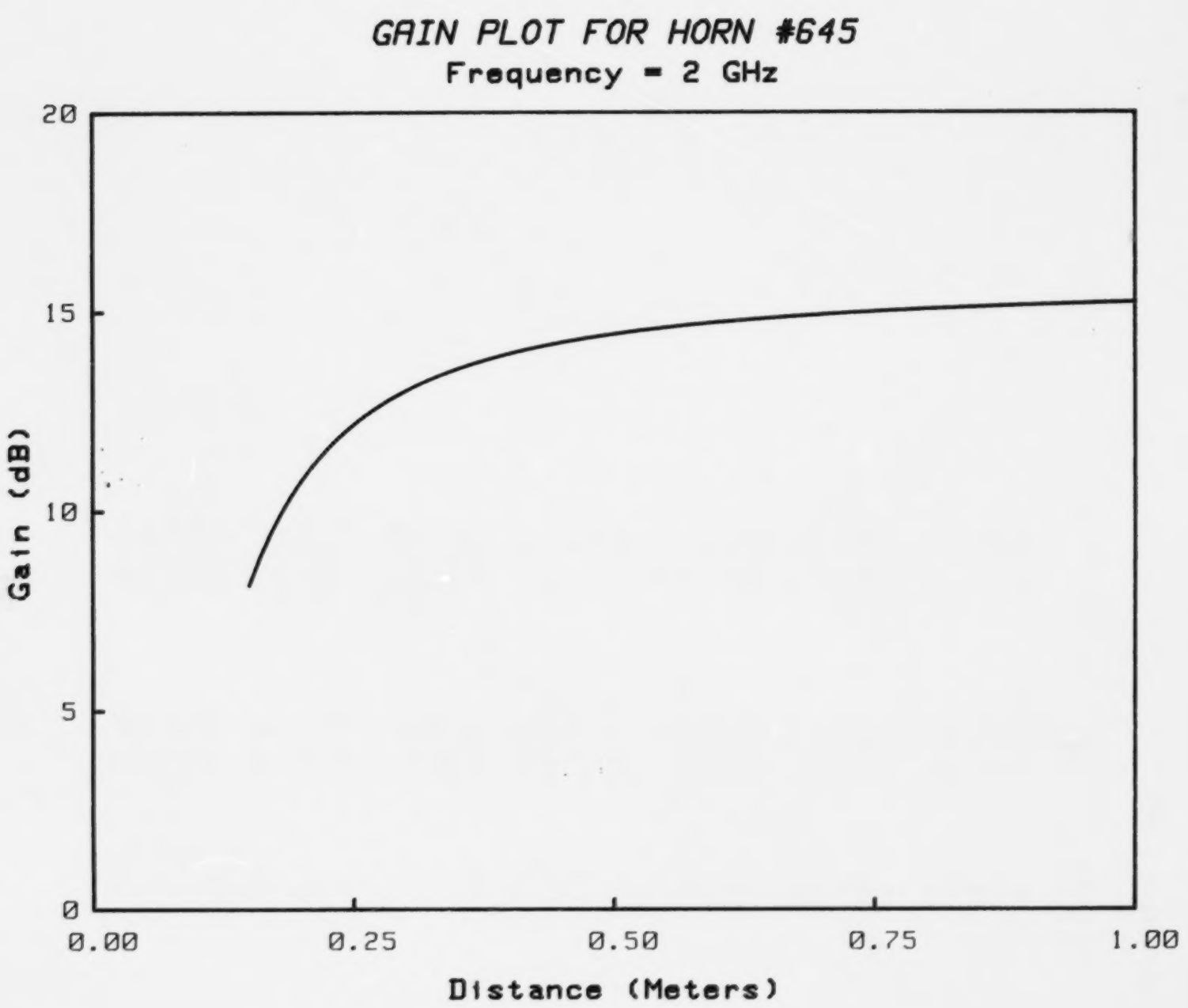
Distance (Meters)	Gain (dB)	Gain Ratio
.15	8.14	6.52
.16	8.82	7.62
.17	9.40	8.72
.18	9.92	9.81
.19	10.36	10.88
.20	10.76	11.91
.21	11.11	12.91
.22	11.42	13.87
.23	11.70	14.79
.24	11.95	15.66
.25	12.17	16.49
.26	12.38	17.28
.27	12.56	18.03
.28	12.73	18.74
.29	12.88	19.41
.30	13.02	20.04
.31	13.15	20.65
.32	13.27	21.22
.33	13.38	21.76
.34	13.48	22.27
.35	13.57	22.76
.36	13.66	23.22
.37	13.74	23.66
.38	13.82	24.07
.39	13.89	24.47
.40	13.95	24.85
.41	14.02	25.21
.42	14.07	25.55
.43	14.13	25.88
.44	14.18	26.19
.45	14.23	26.49
.46	14.28	26.77
.47	14.32	27.04
.48	14.36	27.30
.49	14.40	27.55

Frequency = 2 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.50	14.44	27.79
.51	14.48	28.02
.52	14.51	28.24
.53	14.54	28.45
.54	14.57	28.66
.55	14.60	28.85
.56	14.63	29.04
.57	14.66	29.22
.58	14.68	29.40
.59	14.71	29.56
.60	14.73	29.73
.61	14.75	29.88
.62	14.78	30.03
.63	14.80	30.18
.64	14.82	30.32
.65	14.84	30.45
.66	14.86	30.59
.67	14.87	30.71
.68	14.89	30.84
.69	14.91	30.96
.70	14.92	31.07
.71	14.94	31.18
.72	14.95	31.29
.73	14.97	31.40
.74	14.98	31.50
.75	15.00	31.60
.76	15.01	31.69
.77	15.02	31.79
.78	15.04	31.88
.79	15.05	31.97
.80	15.06	32.05
.81	15.07	32.14
.82	15.08	32.22
.83	15.09	32.30
.84	15.10	32.38
.85	15.11	32.45
.86	15.12	32.52
.87	15.13	32.59
.88	15.14	32.66
.89	15.15	32.73

Frequency = 2 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.90	15.16	32.80
.91	15.17	32.86
.92	15.18	32.93
.93	15.18	32.99
.94	15.19	33.05
.95	15.20	33.11
.96	15.21	33.16
.97	15.21	33.22
.98	15.22	33.27
.99	15.23	33.33
1.00	15.23	33.38


GAIN PLOT FOR HORN #645
Frequency = 2 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 644

A = 23.1 B = 17.2 Lh = 40.476 Le = 34.914

Frequency Range: 2.6 TO 3.95 GHz

Gains will be Calculated Starting from .1 to 1 in Steps of .01

Frequency = 3 GHz

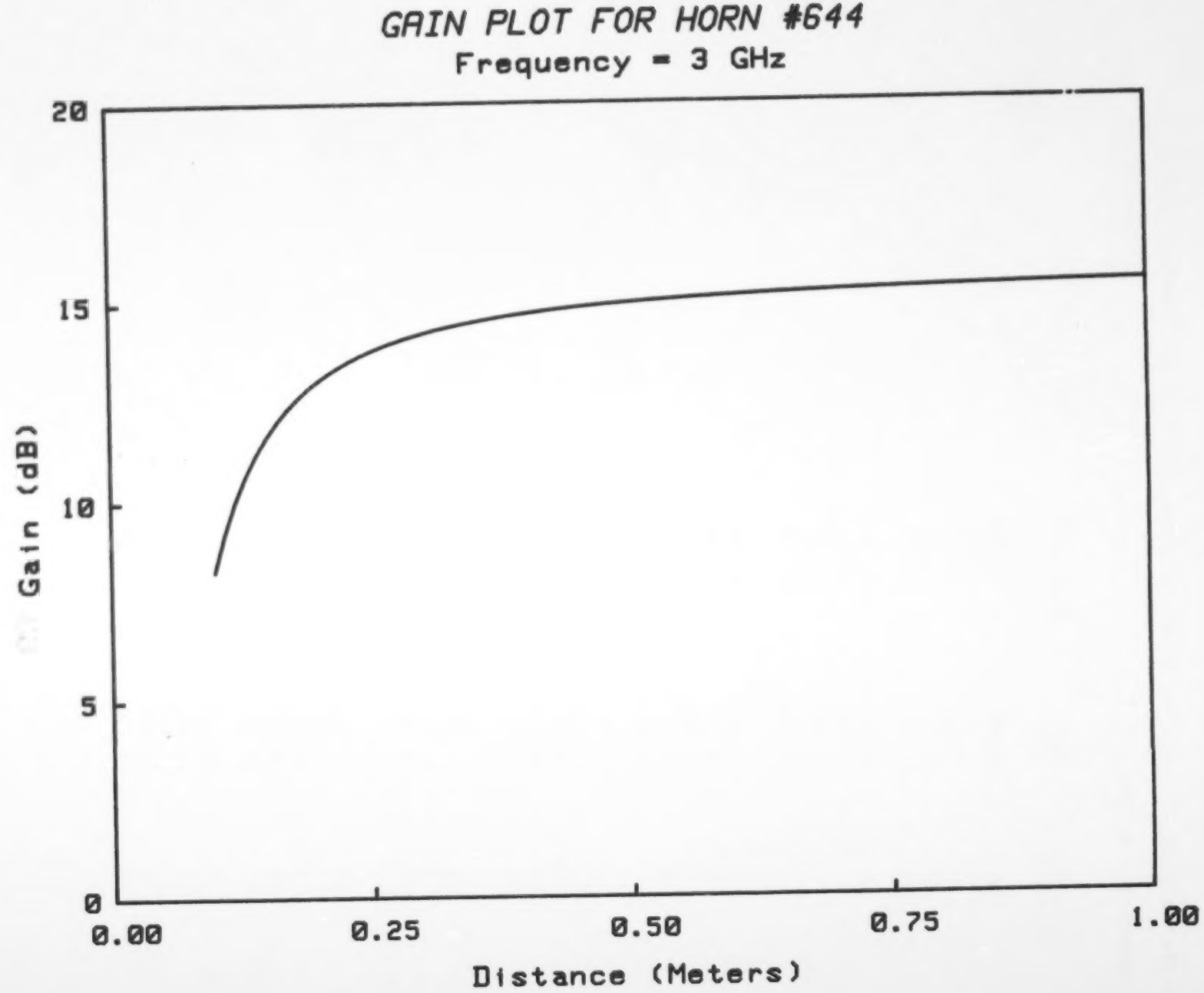
Distance (Meters)	Gain (dB)	Gain Ratio
.10	8.25	6.69
.11	9.21	8.35
.12	9.99	9.99
.13	10.63	11.57
.14	11.16	13.06
.15	11.60	14.46
.16	11.98	15.76
.17	12.30	16.96
.18	12.57	18.07
.19	12.81	19.09
.20	13.02	20.03
.21	13.20	20.89
.22	13.36	21.69
.23	13.51	22.43
.24	13.64	23.10
.25	13.75	23.73
.26	13.86	24.31
.27	13.95	24.85
.28	14.04	25.35
.29	14.12	25.82
.30	14.19	26.25
.31	14.26	26.66
.32	14.32	27.04
.33	14.38	27.39
.34	14.43	27.73
.35	14.48	28.04
.36	14.52	28.34
.37	14.57	28.62
.38	14.61	28.88
.39	14.64	29.13
.40	14.68	29.36
.41	14.71	29.58
.42	14.74	29.80
.43	14.77	30.00
.44	14.80	30.19

Frequency = 3 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.45	14.82	30.37
.46	14.85	30.54
.47	14.87	30.71
.48	14.89	30.86
.49	14.92	31.01
.50	14.94	31.16
.51	14.95	31.30
.52	14.97	31.43
.53	14.99	31.55
.54	15.01	31.67
.55	15.02	31.79
.56	15.04	31.90
.57	15.05	32.01
.58	15.07	32.11
.59	15.08	32.21
.60	15.09	32.31
.61	15.11	32.40
.62	15.12	32.49
.63	15.13	32.57
.64	15.14	32.66
.65	15.15	32.74
.66	15.16	32.81
.67	15.17	32.89
.68	15.18	32.96
.69	15.19	33.03
.70	15.20	33.10
.71	15.21	33.17
.72	15.22	33.23
.73	15.22	33.29
.74	15.23	33.35
.75	15.24	33.41
.76	15.25	33.47
.77	15.25	33.52
.78	15.26	33.57
.79	15.27	33.63
.80	15.27	33.68
.81	15.28	33.73
.82	15.29	33.77
.83	15.29	33.82
.84	15.30	33.86

Frequency = 3 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.85	15.30	33.91
.86	15.31	33.95
.87	15.31	33.99
.88	15.32	34.04
.89	15.32	34.07
.90	15.33	34.11
.91	15.33	34.15
.92	15.34	34.19
.93	15.34	34.22
.94	15.35	34.26
.95	15.35	34.29
.96	15.36	34.33
.97	15.36	34.36
.98	15.36	34.39
.99	15.37	34.42
1.00	15.37	34.46


GAIN PLOT FOR HORN #644
Frequency = 3 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 643

A = 15.25 B = 11.25 Lh = 27.731 Le = 23.186

Frequency Range: 3.95 TO 5.85 GHz

Gains will be Calculated Starting from .05 to 1 in Steps of .01

Frequency = 4 GHz

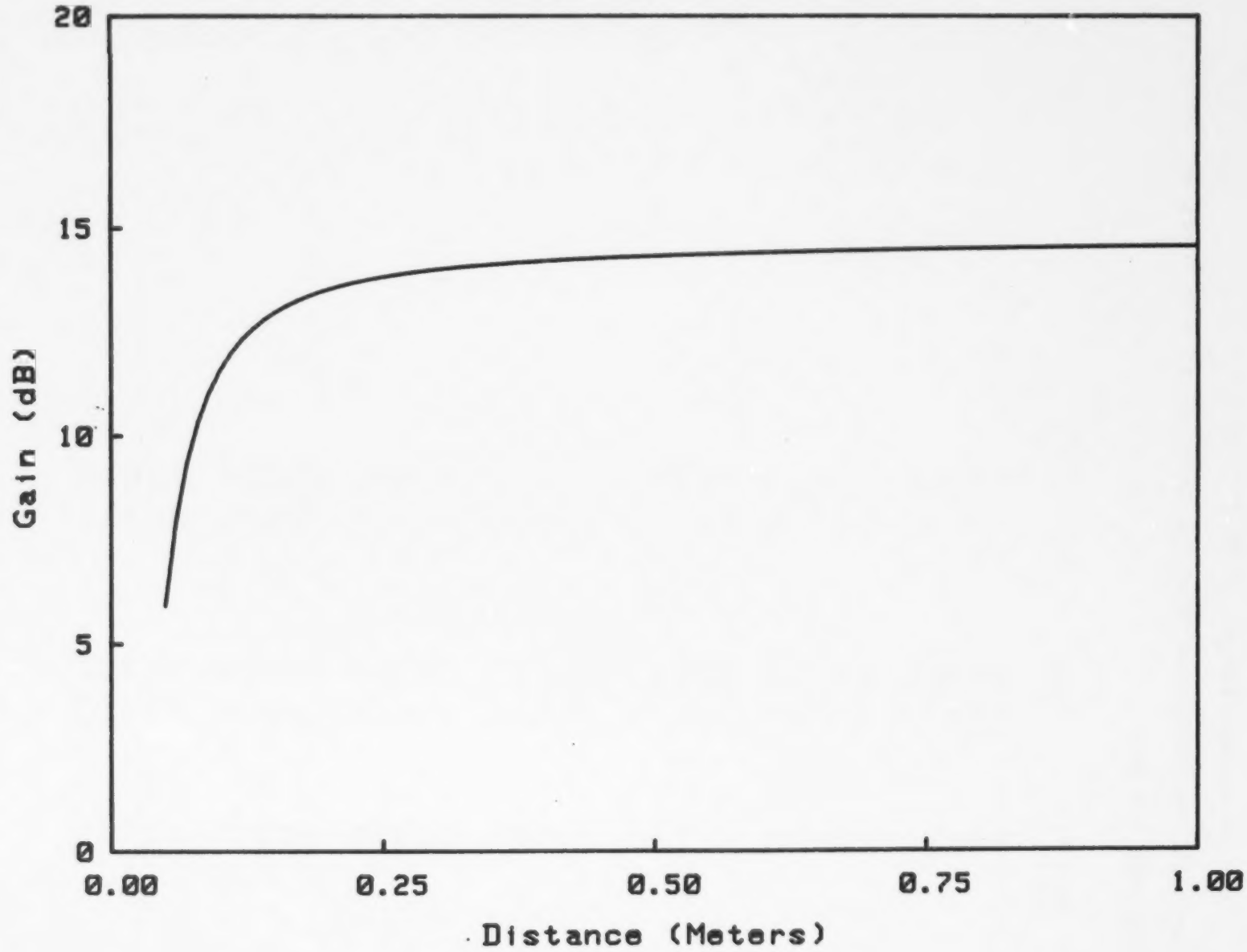
Distance (Meters)	Gain (dB)	Gain Ratio
.05	5.92	3.91
.06	7.95	6.24
.07	9.34	8.59
.08	10.32	10.76
.09	11.03	12.68
.10	11.57	14.35
.11	11.98	15.79
.12	12.31	17.02
.13	12.57	18.08
.14	12.79	19.00
.15	12.97	19.79
.16	13.12	20.49
.17	13.24	21.10
.18	13.35	21.64
.19	13.45	22.12
.20	13.53	22.55
.21	13.61	22.94
.22	13.67	23.28
.23	13.73	23.59
.24	13.78	23.88
.25	13.83	24.14
.26	13.87	24.37
.27	13.91	24.59
.28	13.94	24.79
.29	13.97	24.97
.30	14.00	25.14
.31	14.03	25.30
.32	14.06	25.44
.33	14.08	25.58
.34	14.10	25.71
.35	14.12	25.83
.36	14.14	25.94
.37	14.16	26.04
.38	14.17	26.14
.39	14.19	26.23

Frequency = 4 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.40	14.20	26.32
.41	14.22	26.41
.42	14.23	26.48
.43	14.24	26.56
.44	14.25	26.63
.45	14.26	26.70
.46	14.27	26.76
.47	14.28	26.82
.48	14.29	26.88
.49	14.30	26.93
.50	14.31	26.98
.51	14.32	27.04
.52	14.33	27.08
.53	14.33	27.13
.54	14.34	27.17
.55	14.35	27.22
.56	14.35	27.26
.57	14.36	27.30
.58	14.37	27.33
.59	14.37	27.37
.60	14.38	27.40
.61	14.38	27.44
.62	14.39	27.47
.63	14.39	27.50
.64	14.40	27.53
.65	14.40	27.56
.66	14.41	27.59
.67	14.41	27.62
.68	14.42	27.64
.69	14.42	27.67
.70	14.42	27.69
.71	14.43	27.72
.72	14.43	27.74
.73	14.43	27.76
.74	14.44	27.78
.75	14.44	27.81
.76	14.44	27.83
.77	14.45	27.85
.78	14.45	27.87
.79	14.45	27.88

Frequency = 4 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.80	14.46	27.90
.81	14.46	27.92
.82	14.46	27.94
.83	14.46	27.96
.84	14.47	27.97
.85	14.47	27.99
.86	14.47	28.00
.87	14.47	28.02
.88	14.48	28.03
.89	14.48	28.05
.90	14.48	28.06
.91	14.48	28.08
.92	14.49	28.09
.93	14.49	28.10
.94	14.49	28.12
.95	14.49	28.13
.96	14.49	28.14
.97	14.50	28.15
.98	14.50	28.16
.99	14.50	28.18
1.00	14.50	28.19


GAIN PLOT FOR HORN #643
Frequency = 4 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 643

A = 15.25 B = 11.25 Lh = 27.731 Le = 23.186

Frequency Range: 3.95 TO 5.85 GHz

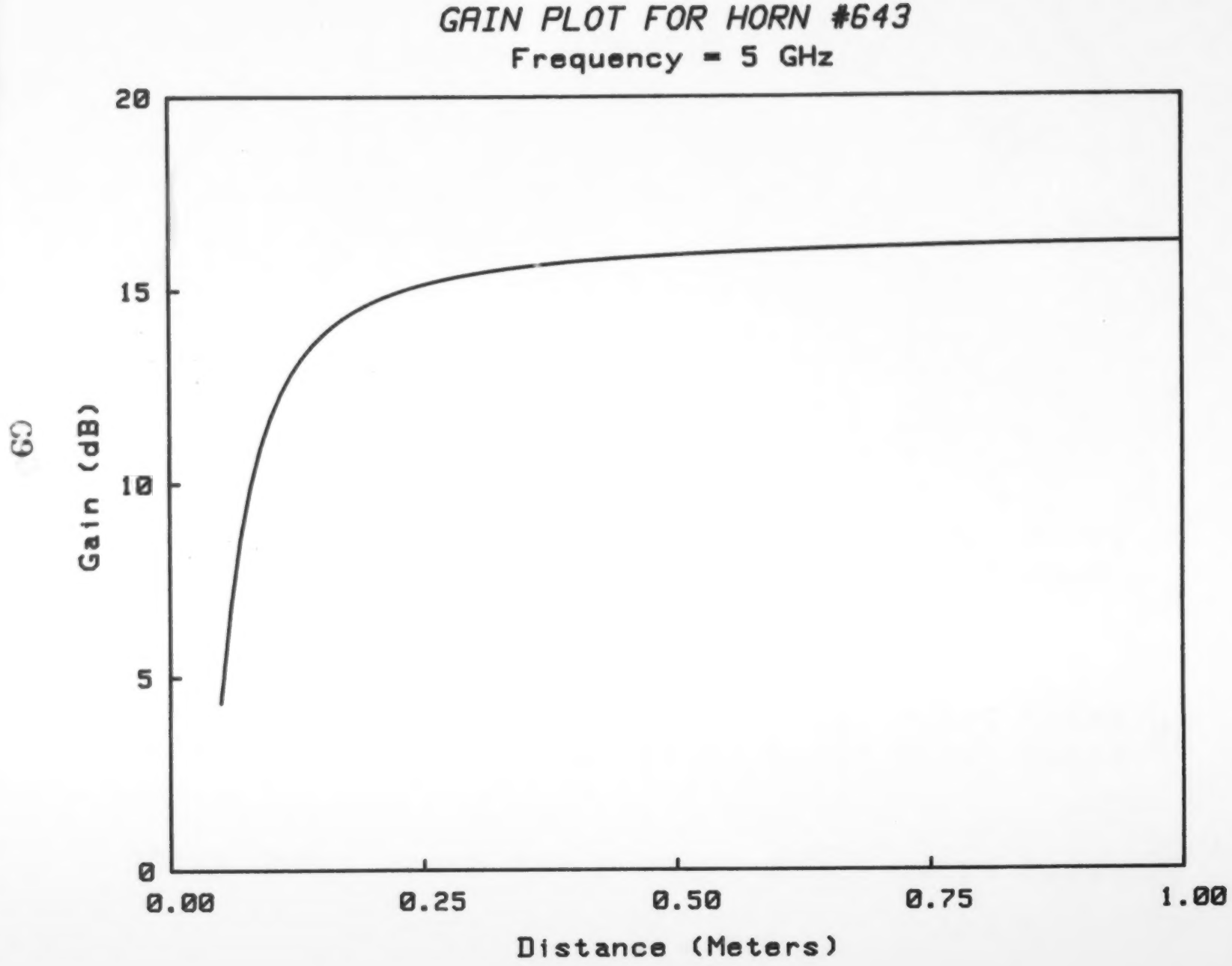
Gains will be Calculated Starting from .05 to 1 in Steps of .01

Frequency = 5 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.05	4.34	2.72
.06	6.73	4.71
.07	8.56	7.18
.08	9.92	9.81
.09	10.94	12.42
.10	11.73	14.88
.11	12.34	17.13
.12	12.83	19.18
.13	13.22	21.01
.14	13.55	22.65
.15	13.82	24.11
.16	14.05	25.43
.17	14.25	26.60
.18	14.42	27.66
.19	14.56	28.61
.20	14.69	29.47
.21	14.81	30.24
.22	14.91	30.95
.23	15.00	31.60
.24	15.08	32.19
.25	15.15	32.73
.26	15.22	33.23
.27	15.28	33.69
.28	15.33	34.12
.29	15.38	34.51
.30	15.43	34.88
.31	15.47	35.22
.32	15.51	35.54
.33	15.54	35.83
.34	15.58	36.11
.35	15.61	36.37
.36	15.64	36.62
.37	15.66	36.85
.38	15.69	37.07
.39	15.71	37.27

Frequency = 5 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.40	15.74	37.47
.41	15.76	37.65
.42	15.78	37.83
.43	15.80	37.99
.44	15.82	38.15
.45	15.83	38.30
.46	15.85	38.45
.47	15.86	38.58
.48	15.88	38.71
.49	15.89	38.83
.50	15.91	38.95
.51	15.92	39.07
.52	15.93	39.18
.53	15.94	39.28
.54	15.95	39.38
.55	15.96	39.48
.56	15.97	39.57
.57	15.98	39.66
.58	15.99	39.74
.59	16.00	39.83
.60	16.01	39.91
.61	16.02	39.98
.62	16.03	40.06
.63	16.03	40.13
.64	16.04	40.20
.65	16.05	40.26
.66	16.06	40.33
.67	16.06	40.39
.68	16.07	40.45
.69	16.08	40.51
.70	16.08	40.57
.71	16.09	40.62
.72	16.09	40.67
.73	16.10	40.72
.74	16.10	40.78
.75	16.11	40.82
.76	16.11	40.87
.77	16.12	40.92
.78	16.12	40.96
.79	16.13	41.01


GAIN PLOT FOR HORN #643
Frequency = 5 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Frequency = 5 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.80	16.13	41.05
.81	16.14	41.09
.82	16.14	41.13
.83	16.15	41.17
.84	16.15	41.21
.85	16.15	41.24
.86	16.16	41.28
.87	16.16	41.31
.88	16.16	41.35
.89	16.17	41.38
.90	16.17	41.42
.91	16.17	41.45
.92	16.18	41.48
.93	16.18	41.51
.94	16.18	41.54
.95	16.19	41.57
.96	16.19	41.60
.97	16.19	41.62
.98	16.20	41.65
.99	16.20	41.68
1.00	16.20	41.70

Dimensions for Horn # 642

A = 11.25 B = 8.3 Lh = 19.946 Le = 17.448

Frequency Range: 5.4 TO 8.2 GHz

Gains will be Calculated Starting from .04 to 1 in Steps of .01

Frequency = 6 GHz

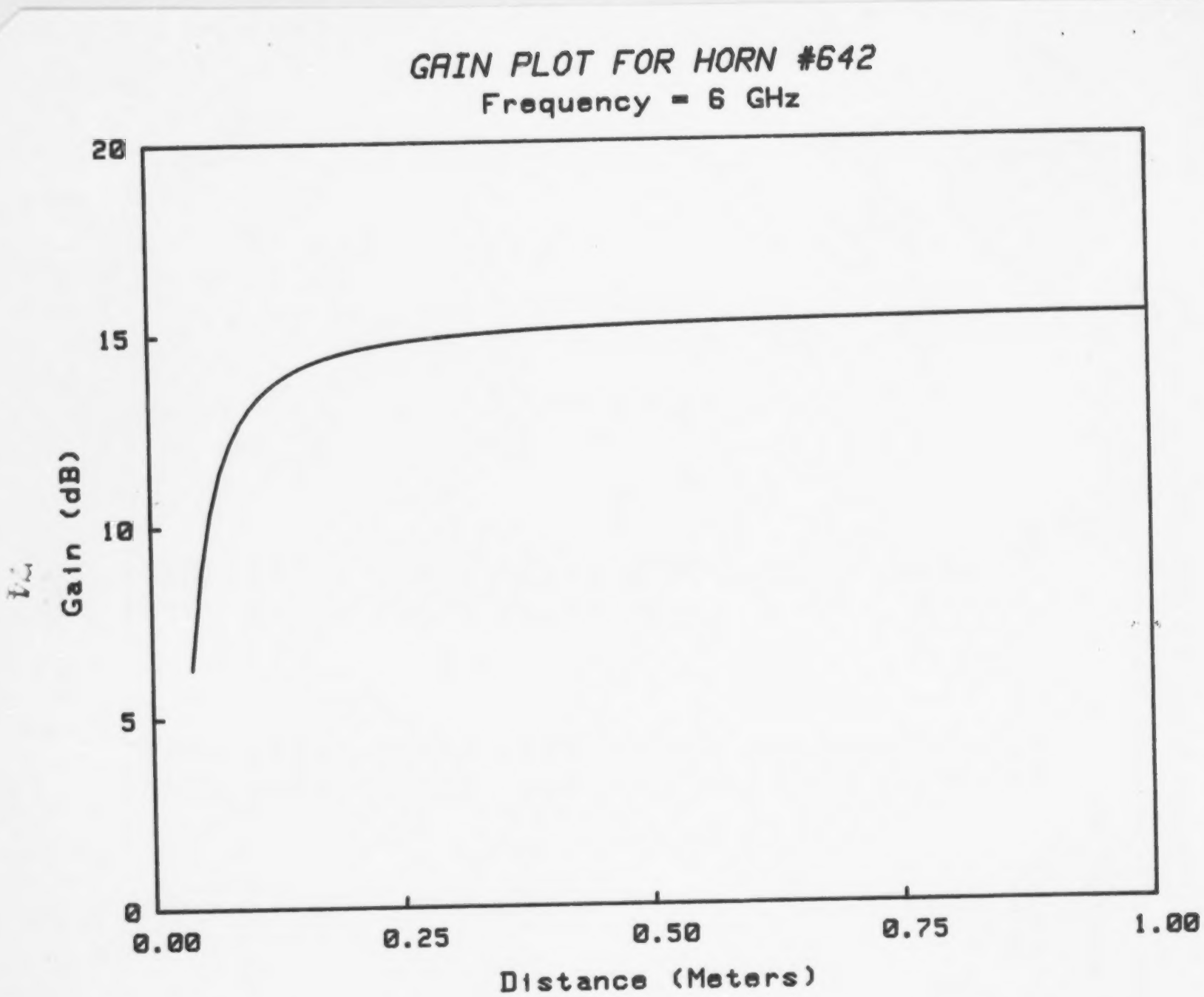
Distance (Meters)	Gain (dB)	Gain Ratio
.04	6.30	4.26
.05	8.78	7.55
.06	10.36	10.87
.07	11.41	13.84
.08	12.14	16.39
.09	12.68	18.52
.10	13.08	20.31
.11	13.39	21.80
.12	13.63	23.07
.13	13.83	24.14
.14	13.99	25.06
.15	14.12	25.85
.16	14.24	26.54
.17	14.34	27.14
.18	14.42	27.67
.19	14.49	28.14
.20	14.56	28.56
.21	14.61	28.94
.22	14.67	29.28
.23	14.71	29.58
.24	14.75	29.86
.25	14.79	30.11
.26	14.82	30.34
.27	14.85	30.56
.28	14.88	30.75
.29	14.90	30.93
.30	14.93	31.10
.31	14.95	31.25
.32	14.97	31.40
.33	14.99	31.53
.34	15.01	31.66
.35	15.02	31.78
.36	15.04	31.89
.37	15.05	31.99
.38	15.06	32.09

Frequency = 6 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.39	15.08	32.18
.40	15.09	32.27
.41	15.10	32.35
.42	15.11	32.43
.43	15.12	32.51
.44	15.13	32.58
.45	15.14	32.64
.46	15.15	32.71
.47	15.15	32.77
.48	15.16	32.83
.49	15.17	32.88
.50	15.18	32.94
.51	15.18	32.99
.52	15.19	33.03
.53	15.20	33.08
.54	15.20	33.13
.55	15.21	33.17
.56	15.21	33.21
.57	15.22	33.25
.58	15.22	33.29
.59	15.23	33.32
.60	15.23	33.36
.61	15.24	33.39
.62	15.24	33.43
.63	15.25	33.46
.64	15.25	33.49
.65	15.25	33.52
.66	15.26	33.55
.67	15.26	33.58
.68	15.26	33.60
.69	15.27	33.63
.70	15.27	33.66
.71	15.27	33.68
.72	15.28	33.70
.73	15.28	33.73
.74	15.28	33.75
.75	15.29	33.77
.76	15.29	33.79
.77	15.29	33.81
.78	15.29	33.83

Frequency = 6 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.79	15.30	33.85
.80	15.30	33.87
.81	15.30	33.89
.82	15.30	33.91
.83	15.31	33.93
.84	15.31	33.94
.85	15.31	33.96
.86	15.31	33.98
.87	15.31	33.99
.88	15.32	34.01
.89	15.32	34.02
.90	15.32	34.04
.91	15.32	34.05
.92	15.32	34.06
.93	15.32	34.08
.94	15.33	34.09
.95	15.33	34.10
.96	15.33	34.12
.97	15.33	34.13
.98	15.33	34.14
.99	15.33	34.15
1.00	15.34	34.17


GAIN PLOT FOR HORN #642
Frequency = 6 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 642

A = 11.25 B = 8.3 Lh = 19.946 Le = 17.448

Frequency Range: 5.4 TO 8.2 GHz

Gains will be Calculated Starting from .03 to 1 in Steps of .01

Frequency = 7 GHz

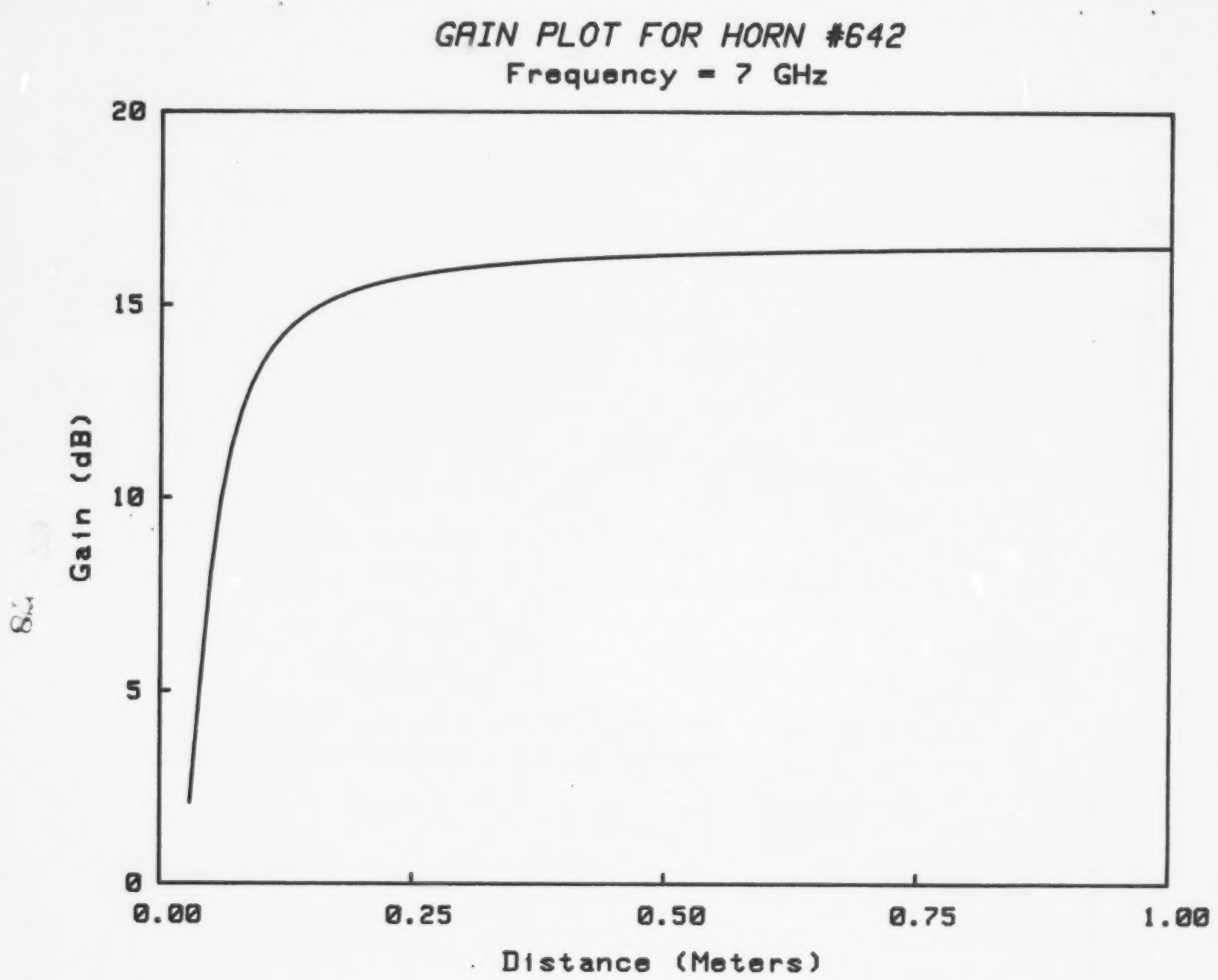
Distance (Meters)	Gain (dB)	Gain Ratio
.03	2.09	1.62
.04	5.21	3.32
.05	8.01	6.33
.06	9.95	9.89
.07	11.29	13.45
.08	12.24	16.73
.09	12.93	19.65
.10	13.46	22.19
.11	13.87	24.39
.12	14.20	26.30
.13	14.46	27.95
.14	14.68	29.39
.15	14.86	30.65
.16	15.02	31.75
.17	15.15	32.73
.18	15.26	33.60
.19	15.36	34.37
.20	15.45	35.07
.21	15.53	35.69
.22	15.59	36.26
.23	15.66	36.77
.24	15.71	37.24
.25	15.76	37.67
.26	15.81	38.07
.27	15.85	38.43
.28	15.88	38.76
.29	15.92	39.07
.30	15.95	39.36
.31	15.98	39.63
.32	16.01	39.88
.33	16.03	40.11
.34	16.06	40.33
.35	16.08	40.53
.36	16.10	40.73
.37	16.12	40.91

Frequency = 7 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.38	16.14	41.08
.39	16.15	41.24
.40	16.17	41.39
.41	16.18	41.54
.42	16.20	41.67
.43	16.21	41.80
.44	16.22	41.93
.45	16.24	42.04
.46	16.25	42.16
.47	16.26	42.26
.48	16.27	42.37
.49	16.28	42.46
.50	16.29	42.56
.51	16.30	42.65
.52	16.31	42.73
.53	16.32	42.81
.54	16.32	42.89
.55	16.33	42.97
.56	16.34	43.04
.57	16.35	43.11
.58	16.35	43.18
.59	16.36	43.24
.60	16.37	43.31
.61	16.37	43.37
.62	16.38	43.43
.63	16.38	43.48
.64	16.39	43.54
.65	16.39	43.59
.66	16.40	43.64
.67	16.40	43.69
.68	16.41	43.74
.69	16.41	43.78
.70	16.42	43.83
.71	16.42	43.87
.72	16.43	43.91
.73	16.43	43.96
.74	16.43	43.99
.75	16.44	44.03
.76	16.44	44.07
.77	16.45	44.11

Frequency = 7 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.78	16.45	44.14
.79	16.45	44.18
.80	16.46	44.21
.81	16.46	44.24
.82	16.46	44.28
.83	16.46	44.31
.84	16.47	44.34
.85	16.47	44.37
.86	16.47	44.40
.87	16.48	44.43
.88	16.48	44.45
.89	16.48	44.48
.90	16.48	44.51
.91	16.49	44.53
.92	16.49	44.56
.93	16.49	44.58
.94	16.49	44.60
.95	16.50	44.63
.96	16.50	44.65
.97	16.50	44.67
.98	16.50	44.69
.99	16.50	44.72
1.00	16.51	44.74


GAIN PLOT FOR HORN #642
Frequency = 7 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 642

A = 11.25 B = 8.3 Lh = 19.946 Le = 17.448

Frequency Range: 5.4 TO 8.2 GHz

Gains will be Calculated Starting from .03 to 1 in Steps of .01

Frequency = 8 GHz

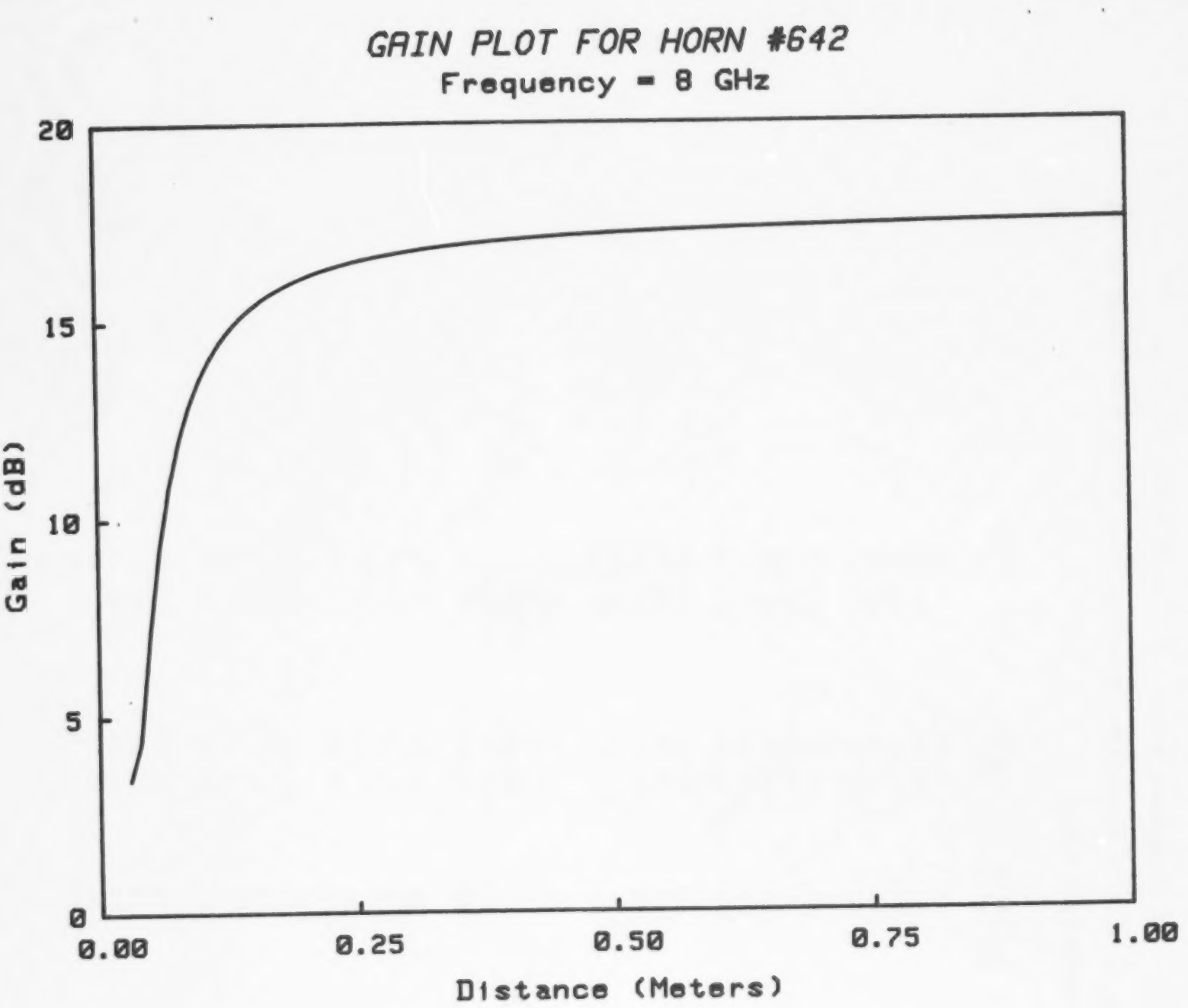
Distance (Meters)	Gain (dB)	Gain Ratio
.03	3.41	2.19
.04	4.34	2.72
.05	7.09	5.12
.06	9.28	8.46
.07	10.86	12.20
.08	12.02	15.93
.09	12.89	19.45
.10	13.55	22.66
.11	14.07	25.55
.12	14.49	28.11
.13	14.83	30.39
.14	15.11	32.40
.15	15.34	34.20
.16	15.54	35.79
.17	15.71	37.22
.18	15.85	38.50
.19	15.98	39.65
.20	16.10	40.69
.21	16.20	41.64
.22	16.28	42.50
.23	16.36	43.28
.24	16.43	44.00
.25	16.50	44.66
.26	16.56	45.27
.27	16.61	45.83
.28	16.66	46.35
.29	16.71	46.83
.30	16.75	47.28
.31	16.79	47.70
.32	16.82	48.09
.33	16.85	48.46
.34	16.88	48.80
.35	16.91	49.12
.36	16.94	49.43
.37	16.96	49.71

Frequency = 8 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.38	16.99	49.99
.39	17.01	50.24
.40	17.03	50.48
.41	17.05	50.71
.42	17.07	50.93
.43	17.09	51.14
.44	17.10	51.34
.45	17.12	51.52
.46	17.14	51.70
.47	17.15	51.87
.48	17.16	52.04
.49	17.18	52.20
.50	17.19	52.34
.51	17.20	52.49
.52	17.21	52.63
.53	17.22	52.76
.54	17.23	52.88
.55	17.24	53.01
.56	17.25	53.12
.57	17.26	53.24
.58	17.27	53.35
.59	17.28	53.45
.60	17.29	53.55
.61	17.30	53.65
.62	17.30	53.75
.63	17.31	53.84
.64	17.32	53.92
.65	17.32	54.01
.66	17.33	54.09
.67	17.34	54.17
.68	17.34	54.25
.69	17.35	54.33
.70	17.36	54.40
.71	17.36	54.47
.72	17.37	54.54
.73	17.37	54.60
.74	17.38	54.67
.75	17.38	54.73
.76	17.39	54.79
.77	17.39	54.85

Frequency = 8 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.78	17.40	54.91
.79	17.40	54.97
.80	17.41	55.02
.81	17.41	55.07
.82	17.41	55.13
.83	17.42	55.18
.84	17.42	55.23
.85	17.43	55.27
.86	17.43	55.32
.87	17.43	55.37
.88	17.44	55.41
.89	17.44	55.45
.90	17.44	55.50
.91	17.45	55.54
.92	17.45	55.58
.93	17.45	55.62
.94	17.46	55.66
.95	17.46	55.70
.96	17.46	55.73
.97	17.46	55.77
.98	17.47	55.81
.99	17.47	55.84
1.00	17.47	55.88


GAIN PLOT FOR HORN #642
Frequency = 8 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 640

A = 7.35 B = 5.5 Lh = 13.094 Le = 10.991

Frequency Range: 8.2 TO 12.4 GHz

Gains will be Calculated Starting from .03 to 1 in Steps of .01

Frequency = 9 GHz

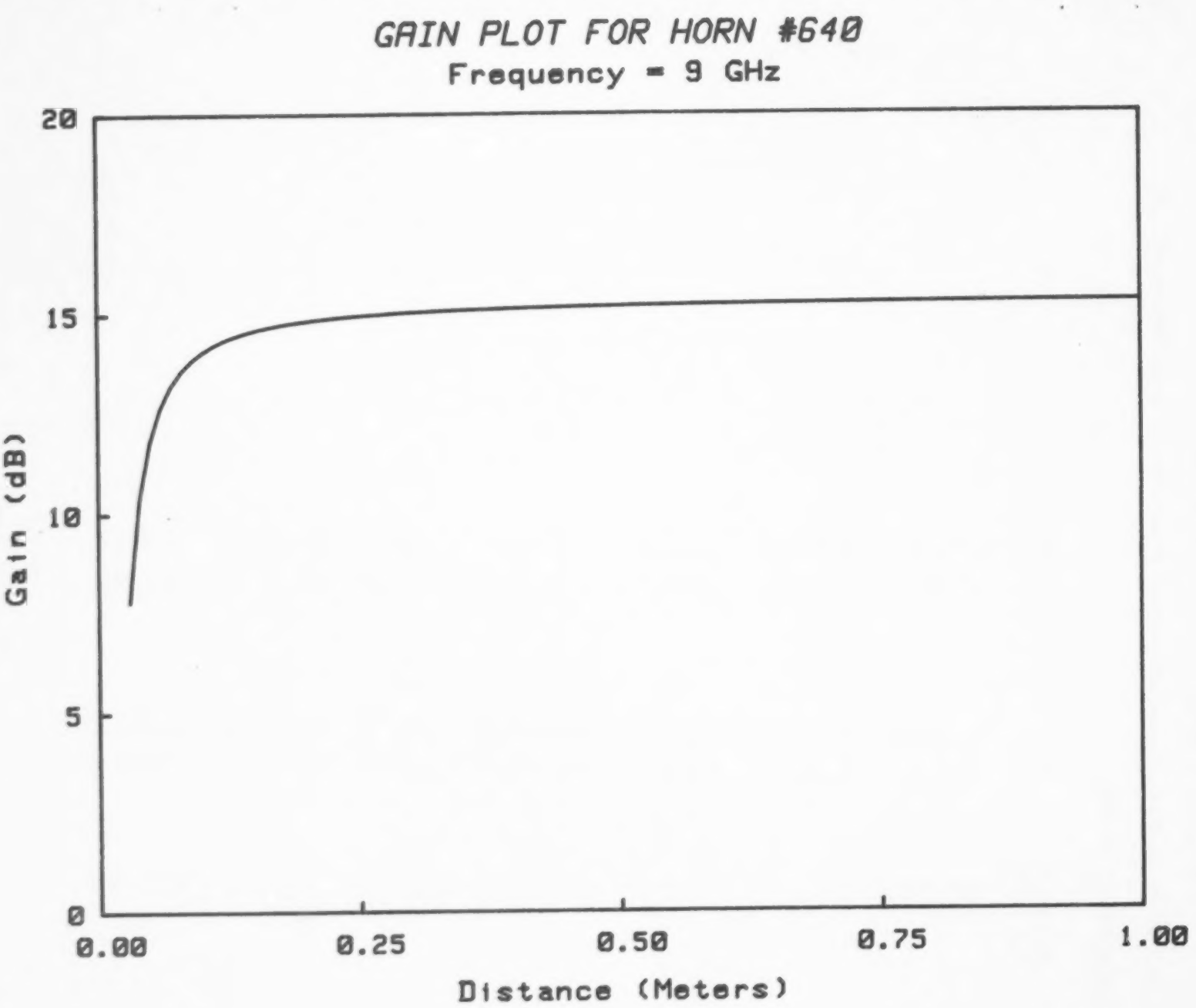
Distance (Meters)	Gain (dB)	Gain Ratio
.03	7.79	6.02
.04	10.42	11.02
.05	11.82	15.22
.06	12.66	18.45
.07	13.20	20.90
.08	13.58	22.78
.09	13.85	24.25
.10	14.05	25.42
.11	14.21	26.37
.12	14.34	27.14
.13	14.44	27.79
.14	14.52	28.34
.15	14.59	28.80
.16	14.65	29.20
.17	14.71	29.55
.18	14.75	29.86
.19	14.79	30.13
.20	14.83	30.37
.21	14.86	30.59
.22	14.88	30.78
.23	14.91	30.96
.24	14.93	31.12
.25	14.95	31.26
.26	14.97	31.40
.27	14.99	31.52
.28	15.00	31.63
.29	15.02	31.73
.30	15.03	31.83
.31	15.04	31.92
.32	15.05	32.00
.33	15.06	32.08
.34	15.07	32.15
.35	15.08	32.22
.36	15.09	32.29
.37	15.10	32.35

Frequency = 9 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.38	15.11	32.40
.39	15.11	32.46
.40	15.12	32.51
.41	15.13	32.56
.42	15.13	32.60
.43	15.14	32.64
.44	15.14	32.69
.45	15.15	32.72
.46	15.15	32.76
.47	15.16	32.80
.48	15.16	32.83
.49	15.17	32.86
.50	15.17	32.90
.51	15.18	32.93
.52	15.18	32.95
.53	15.18	32.98
.54	15.19	33.01
.55	15.19	33.03
.56	15.19	33.06
.57	15.20	33.08
.58	15.20	33.10
.59	15.20	33.12
.60	15.20	33.15
.61	15.21	33.17
.62	15.21	33.19
.63	15.21	33.20
.64	15.21	33.22
.65	15.22	33.24
.66	15.22	33.26
.67	15.22	33.27
.68	15.22	33.29
.69	15.23	33.31
.70	15.23	33.32
.71	15.23	33.34
.72	15.23	33.35
.73	15.23	33.36
.74	15.23	33.38
.75	15.24	33.39
.76	15.24	33.40
.77	15.24	33.41

Frequency = 9 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.78	15.24	33.43
.79	15.24	33.44
.80	15.24	33.45
.81	15.25	33.46
.82	15.25	33.47
.83	15.25	33.48
.84	15.25	33.49
.85	15.25	33.50
.86	15.25	33.51
.87	15.25	33.52
.88	15.25	33.53
.89	15.26	33.54
.90	15.26	33.55
.91	15.26	33.56
.92	15.26	33.57
.93	15.26	33.57
.94	15.26	33.58
.95	15.26	33.59
.96	15.26	33.60
.97	15.26	33.61
.98	15.27	33.61
.99	15.27	33.62
1.00	15.27	33.63


GAIN PLOT FOR HORN #640
Frequency = 9 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 640

A = 7.35 B = 5.5 Lh = 13.094 Le = 10.991

Frequency Range: 8.2 TO 12.4 GHz

Gains will be Calculated Starting from .02 to 1 in Steps of .01

Frequency = 10 GHz

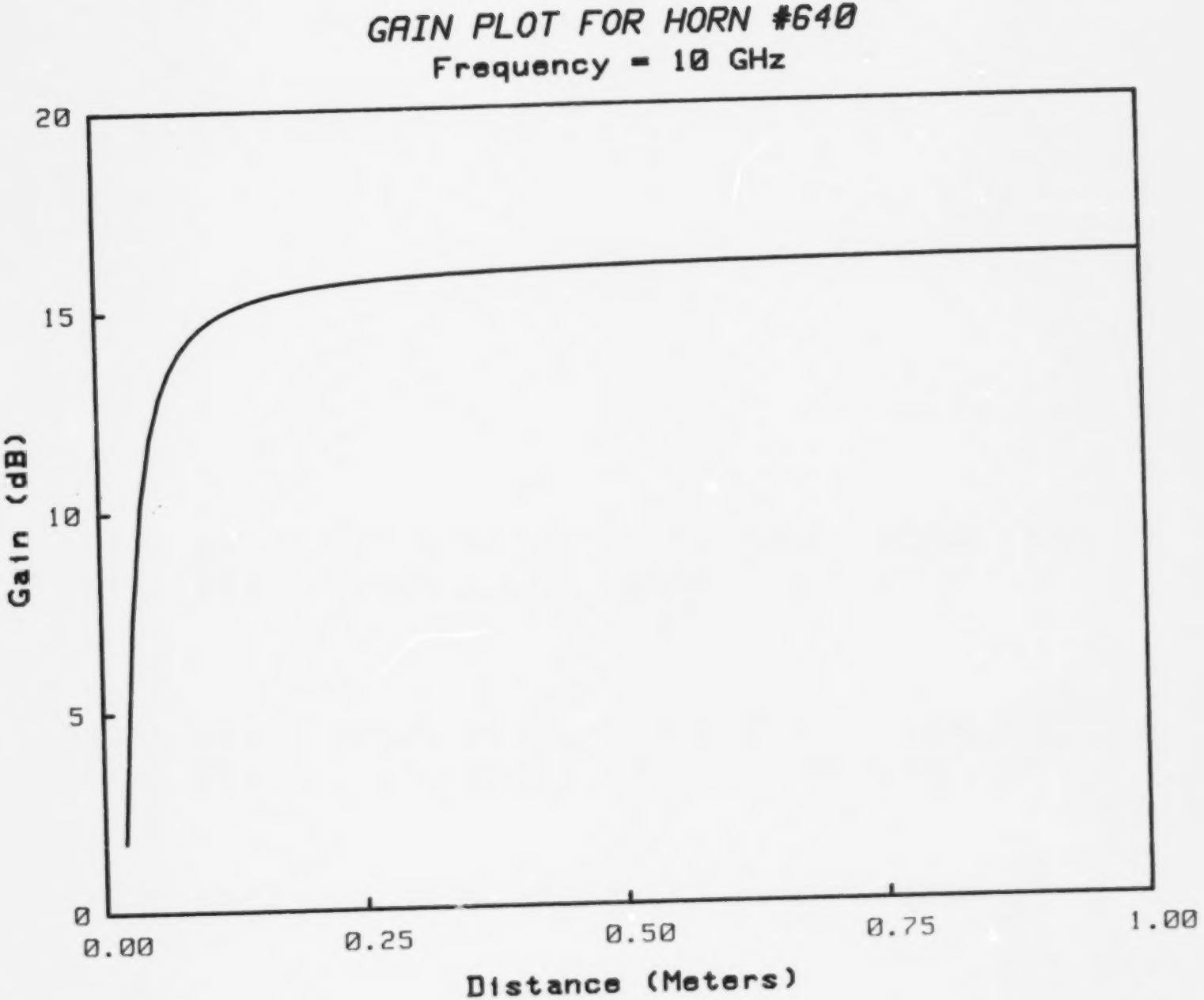
Distance (Meters)	Gain (dB)	Gain Ratio
.02	1.75	1.50
.03	7.17	5.21
.04	10.20	10.47
.05	11.87	15.40
.06	12.88	19.43
.07	13.54	22.62
.08	14.00	25.13
.09	14.33	27.13
.10	14.59	28.74
.11	14.78	30.06
.12	14.94	31.15
.13	15.06	32.07
.14	15.17	32.85
.15	15.25	33.52
.16	15.33	34.10
.17	15.39	34.60
.18	15.45	35.05
.19	15.49	35.44
.20	15.54	35.79
.21	15.58	36.10
.22	15.61	36.39
.23	15.64	36.64
.24	15.67	36.87
.25	15.69	37.09
.26	15.72	37.28
.27	15.74	37.46
.28	15.75	37.63
.29	15.77	37.78
.30	15.79	37.92
.31	15.80	38.05
.32	15.82	38.17
.33	15.83	38.29
.34	15.84	38.40
.35	15.85	38.50
.36	15.86	38.59

Frequency = 10 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.37	15.87	38.68
.38	15.88	38.76
.39	15.89	38.84
.40	15.90	38.92
.41	15.91	38.99
.42	15.92	39.06
.43	15.92	39.12
.44	15.93	39.18
.45	15.94	39.24
.46	15.94	39.30
.47	15.95	39.35
.48	15.95	39.40
.49	15.96	39.45
.50	15.97	39.49
.51	15.97	39.54
.52	15.97	39.58
.53	15.98	39.62
.54	15.98	39.66
.55	15.99	39.70
.56	15.99	39.73
.57	16.00	39.77
.58	16.00	39.80
.59	16.00	39.83
.60	16.01	39.87
.61	16.01	39.90
.62	16.01	39.92
.63	16.02	39.95
.64	16.02	39.98
.65	16.02	40.01
.66	16.02	40.03
.67	16.03	40.06
.68	16.03	40.08
.69	16.03	40.10
.70	16.03	40.13
.71	16.04	40.15
.72	16.04	40.17
.73	16.04	40.19
.74	16.04	40.21
.75	16.05	40.23
.76	16.05	40.25

Frequency = 10 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.77	16.05	40.27
.78	16.05	40.28
.79	16.05	40.30
.80	16.06	40.32
.81	16.06	40.33
.82	16.06	40.35
.83	16.06	40.37
.84	16.06	40.38
.85	16.06	40.40
.86	16.07	40.41
.87	16.07	40.42
.88	16.07	40.44
.89	16.07	40.45
.90	16.07	40.47
.91	16.07	40.48
.92	16.07	40.49
.93	16.07	40.50
.94	16.08	40.52
.95	16.08	40.53
.96	16.08	40.54
.97	16.08	40.55
.98	16.08	40.56
.99	16.08	40.57
1.00	16.08	40.58


GAIN PLOT FOR HORN #640
Frequency = 10 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 640

A = 7.35 B = 5.5 Lh = 13.094 Le = 10.991

Frequency Range: 8.2 TO 12.4 GHz

Gains will be Calculated Starting from .02 to 1 in Steps of .01

Frequency = 11 GHz

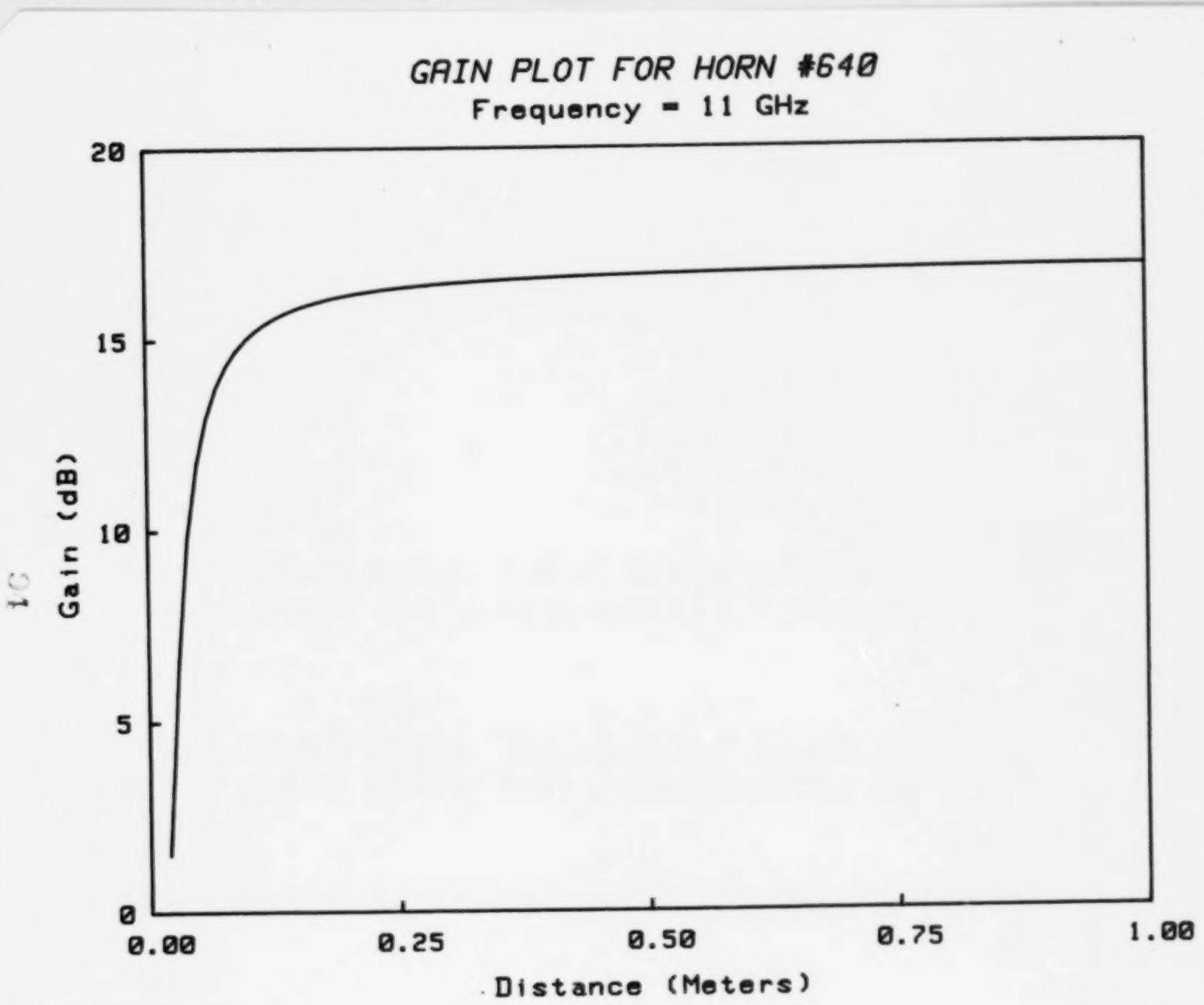
Distance (Meters)	Gain (dB)	Gain Ratio
.02	1.51	1.42
.03	6.45	4.42
.04	9.83	9.62
.05	11.77	15.04
.06	12.96	19.79
.07	13.75	23.70
.08	14.29	26.88
.09	14.69	29.46
.10	14.99	31.57
.11	15.23	33.32
.12	15.41	34.79
.13	15.57	36.03
.14	15.69	37.08
.15	15.80	38.00
.16	15.89	38.79
.17	15.96	39.48
.18	16.03	40.10
.19	16.09	40.64
.20	16.14	41.13
.21	16.19	41.56
.22	16.23	41.96
.23	16.27	42.32
.24	16.30	42.64
.25	16.33	42.94
.26	16.36	43.21
.27	16.38	43.46
.28	16.40	43.69
.29	16.43	43.91
.30	16.45	44.11
.31	16.46	44.29
.32	16.48	44.47
.33	16.50	44.63
.34	16.51	44.78
.35	16.52	44.92
.36	16.54	45.06

Frequency = 11 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.77	16.76	47.43
.78	16.76	47.46
.79	16.77	47.48
.80	16.77	47.51
.81	16.77	47.53
.82	16.77	47.55
.83	16.77	47.58
.84	16.78	47.60
.85	16.78	47.62
.86	16.78	47.64
.87	16.78	47.66
.88	16.78	47.68
.89	16.79	47.70
.90	16.79	47.72
.91	16.79	47.74
.92	16.79	47.76
.93	16.79	47.77
.94	16.79	47.79
.95	16.79	47.81
.96	16.80	47.82
.97	16.80	47.84
.98	16.80	47.86
.99	16.80	47.87
1.00	16.80	47.89

Frequency = 11 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.37	16.55	45.18
.38	16.56	45.30
.39	16.57	45.41
.40	16.58	45.52
.41	16.59	45.62
.42	16.60	45.72
.43	16.61	45.81
.44	16.62	45.89
.45	16.63	45.97
.46	16.63	46.05
.47	16.64	46.13
.48	16.65	46.20
.49	16.65	46.27
.50	16.66	46.33
.51	16.66	46.40
.52	16.67	46.46
.53	16.68	46.51
.54	16.68	46.57
.55	16.69	46.62
.56	16.69	46.68
.57	16.70	46.73
.58	16.70	46.77
.59	16.70	46.82
.60	16.71	46.86
.61	16.71	46.91
.62	16.72	46.95
.63	16.72	46.99
.64	16.72	47.03
.65	16.73	47.06
.66	16.73	47.10
.67	16.73	47.13
.68	16.74	47.17
.69	16.74	47.20
.70	16.74	47.23
.71	16.75	47.27
.72	16.75	47.30
.73	16.75	47.32
.74	16.75	47.35
.75	16.76	47.38
.76	16.76	47.41


GAIN PLOT FOR HORN #640
Frequency = 11 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

Dimensions for Horn # 640

A = 7.35 B = 5.5 Lh = 13.094 Le = 10.991

Frequency Range: 8.2 TO 12.4 GHz

Gains will be Calculated Starting from .02 to 1 in Steps of .01

Frequency = 12 GHz

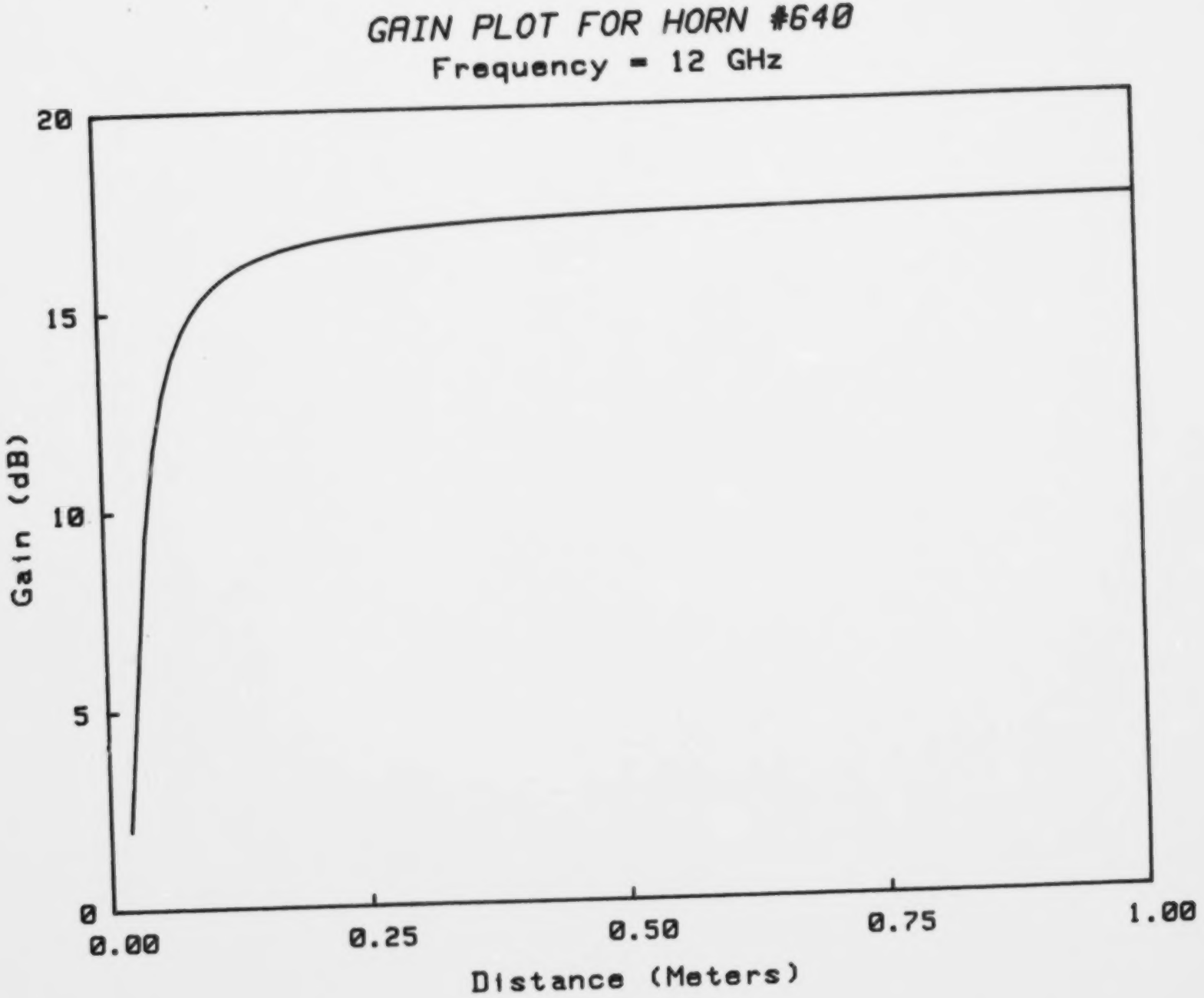
Distance (Meters)	Gain (dB)	Gain Ratio
.02	1.99	1.58
.03	5.73	3.74
.04	9.35	8.62
.05	11.55	14.28
.06	12.92	19.58
.07	13.83	24.16
.08	14.47	27.99
.09	14.94	31.18
.10	15.29	33.83
.11	15.57	36.05
.12	15.79	37.93
.13	15.97	39.54
.14	16.12	40.91
.15	16.24	42.11
.16	16.35	43.15
.17	16.44	44.07
.18	16.52	44.89
.19	16.59	45.61
.20	16.65	46.26
.21	16.71	46.84
.22	16.76	47.37
.23	16.80	47.85
.24	16.84	48.29
.25	16.87	48.69
.26	16.91	49.06
.27	16.94	49.40
.28	16.96	49.71
.29	16.99	50.00
.30	17.01	50.27
.31	17.04	50.52
.32	17.06	50.76
.33	17.07	50.98
.34	17.09	51.18
.35	17.11	51.38
.36	17.12	51.56

Frequency = 12 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.37	17.14	51.73
.38	17.15	51.89
.39	17.16	52.05
.40	17.18	52.19
.41	17.19	52.33
.42	17.20	52.46
.43	17.21	52.58
.44	17.22	52.70
.45	17.23	52.81
.46	17.24	52.92
.47	17.24	53.02
.48	17.25	53.12
.49	17.26	53.22
.50	17.27	53.31
.51	17.27	53.39
.52	17.28	53.47
.53	17.29	53.55
.54	17.29	53.63
.55	17.30	53.70
.56	17.31	53.77
.57	17.31	53.84
.58	17.32	53.91
.59	17.32	53.97
.60	17.33	54.03
.61	17.33	54.09
.62	17.34	54.15
.63	17.34	54.20
.64	17.34	54.26
.65	17.35	54.31
.66	17.35	54.36
.67	17.36	54.41
.68	17.36	54.45
.69	17.36	54.50
.70	17.37	54.54
.71	17.37	54.58
.72	17.37	54.63
.73	17.38	54.67
.74	17.38	54.71
.75	17.38	54.74
.76	17.39	54.78

Frequency = 12 GHz

Distance (Meters)	Gain (dB)	Gain Ratio
.77	17.39	54.82
.78	17.39	54.85
.79	17.39	54.88
.80	17.40	54.92
.81	17.40	54.95
.82	17.40	54.98
.83	17.40	55.01
.84	17.41	55.04
.85	17.41	55.07
.86	17.41	55.10
.87	17.41	55.13
.88	17.42	55.16
.89	17.42	55.18
.90	17.42	55.21
.91	17.42	55.23
.92	17.42	55.26
.93	17.43	55.28
.94	17.43	55.31
.95	17.43	55.33
.96	17.43	55.35
.97	17.43	55.37
.98	17.43	55.40
.99	17.44	55.42
1.00	17.44	55.44


GAIN PLOT FOR HORN #640
Frequency = 12 GHz
20
15
10
5
0
Gain (dB)
0.00
0.25
0.50
0.75
1.00
Distance (Meters)

APPENDIX B

ANECHOIC MATERIAL SPECIFICATIONS

AND

DATA OBTAINED FROM

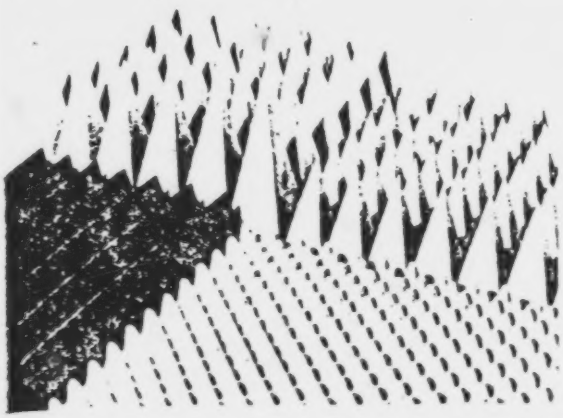
RANGE REFLECTION TESTS

Microwave Absorbers

Type AAP

HIGH PERFORMANCE

BROADBAND



vanced Absorber Products has available a complete line of
performance microwave absorbers in a wide range of
nesses and absorbancies.

nstructed of low density, flexible foam, these solid
amidal and convoluted absorbers are impregnated with a
uctive black formulation to achieve the desired electrical
mance. They provide engineers with the building
ks needed in the design and construction of RF absorb-
surfaces used in anechoic chambers, antenna assemblies
microwave measuring facilities.

Types:

-C Convoluted

-P Pyramidal

-WR Absorber material encapsulated in a rigid foam and covered with a weather-resistant fabric suitable for outdoor applications.

-FL Similar construction to WR except without fabric but with a load-bearing flat top surface suitable for walkways and platforms.

-V An open cell foam (10 pores/in) allows for the flow of air through the absorber for venting and outdoor applications. Cooling air circulated through this material allows for use in applications of RF power up to 10 watts/in^2.

-W Wedge shaped absorbers used to attain maximum performance at grazing incidence angles.

ECIFICATIONS

pe	Nominal (in)	Thickness (cm)	Peaks/ Block	Absorption (dB @ f in MHz or band designation) 120	200	300	500	1000	S	C	X	Ku	K
P 1.5C	1.5	4	360							20	30	35	45
P 3C	3	8	360							30	40	45	50
P 3P	3	8	256							30	40	45	50
P-4C	4	10	360						30	40	45	50	50
P-4P	4	10	144						30	40	45	50	50
P-5	5	13	144						35	45	50	50	50
P-8	8	20	81					30	40	45	50	50	50
P-12	12	30	36				30	35	40	45	50	50	50
P-18	18	46	16				30	40	45	50	50	50	50
P-24	24	61	9			30	35	40	50	50	50	50	50
P 30	30	76	9			30	35	40	50	50	50	50	50
P 36	36	91	4		30	35	40	45	50	50	50	50	50
P-48	48	122	4		30	35	40	45	50	50	50	50	50
P-72	72	183	1	30	35	40	45	50	50	50	50	50	50

or: Standard - light blue (black and other colors available on request.)

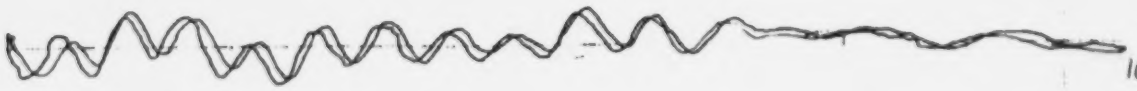
e Standard - 24 by 24 inches (61 by 61 cm) nominal (other sizes available on request).

dard products are self-extinguishing per ASTM-1692. A highly fire retardant grade designated FR is also available.

sorption characteristics are relative to metal surface @ 100% R^2 or 0 dB.

Reproduced from best available copy.

red- pulling
black - pushing



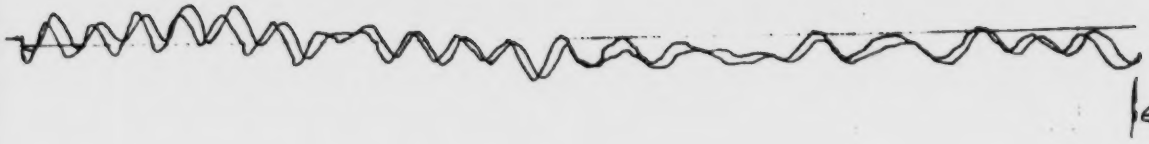
2.7 G-Hz

red - pull

black - push

3.0 cHe

probe 47 cm from here start - probe 40 cm from back wall

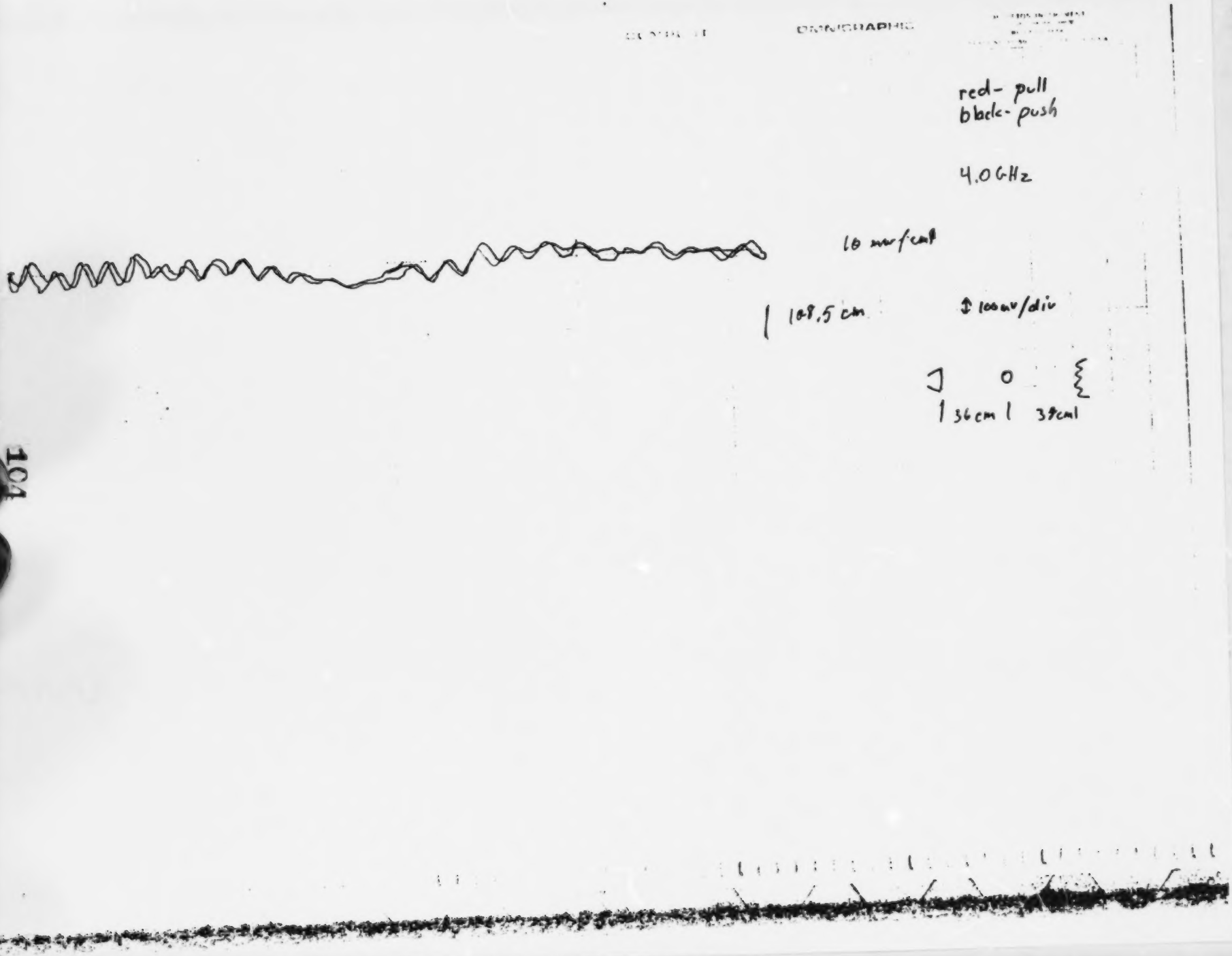


108.5 cm

red - pull
black - push

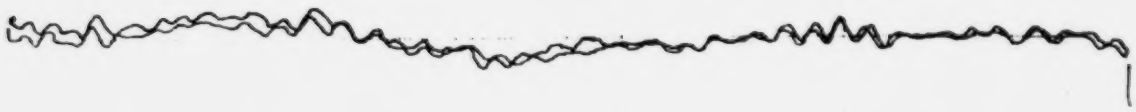
probe 31 cm from horn

↕ mm/div


red- pull
black- push
4.0 GHz
10 mw/cm²
108.5 cm
100 mv/div
0
36 cm
39 cm

red- pull
black- push
5.0 GHz
10 mw/cm²
10 mw/div
0
3 cm
3 cm
10K.5 cm

red- pull
black- push
6.0 GHz
100 mv/div
0
37.5cm
38cm
10 mm
108.5 cm



red- pull
black- push
7.0 GHz

— 10 mw/cm²

108.5 cm

↕ 100mv/div

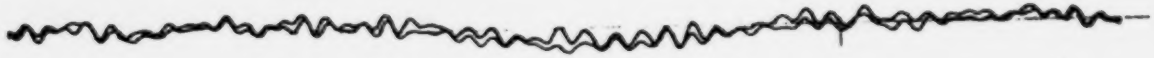
0

37.5cm | 38cm

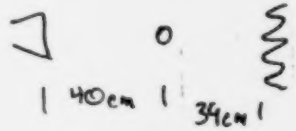
107

pull - red
push - black
8.0 GHz

d = 108.5 cm



10 mV



APPENDIX C

LISTING OF HORNGO PROGRAM

AND

ILLUSTRATIVE RUNS

```
10   !          H     H    OOOOO   RRRRRR    N     N   GGGGG     OOOOO
20   !          H     H   O     O  R     R   NN    N  G     G   O     O
30   !          H     H   O     O  R     R   N N   N  G         O     O
40   !          HHHHHHH   O     O  RRRRRR    N  N  N  G   GGG   O     O
50   !          H     H   O     O  R   R     N   N N  G     G   O     O
60   !          H     H   O     O  R    R    N    NN  G     G   O     O
70   !          H     H    OOOOO   R     R   N     N   GGGGG     OOOOO
80   !
90   ! ************************************************************************
100  ! *                                                                      *
110  ! *  PROGRAM NAME: HORNGO                          REVISION: A  05/19/83 *
120  ! *                                                                      *
130  ! *  COMPUTER: HP 9845B                                                  *
140  ! *                                                                      *
150  ! *  PROGRAMMERS:  Michael R. Molony, Edwin D. Mantiply and              *
160  ! *                Jerry C. Johnson - Non-Ionizing Radiation Branch      *
170  ! *                                                                      *
180  ! *  DESCRIPTION:                                                        *
190  ! *     This program will generate accurately known electromagnetic      *
200  ! *     field intensities for the purpose of evaluating the response     *
210  ! *     of broadband, isotropic microwave measurement probes. This       *
220  ! *     system provides a convenient and accurate method to evaluate     *
230  ! *     measurement probe response to microwave fields and therefore     *
240  ! *     establish uncertainty limits for instrument readings obtained    *
250  ! *     in hazard survey measurements.                                   *
260  ! *                                                                      *
270  ! *  WARRANTY:                                                           *
280  ! *     The Non-Ionizing Radiation Branch of EPA warrants only that      *
290  ! *     testing has been applied to this code. No other warranty         *
300  ! *     expressed or implied, is applicable.                             *
310  ! *                                                                      *
320  ! ************************************************************************
330  !
340  !
350  !
360  !
370  ! 0.0     HPIB DEVICE ADDRESSES      Select Code #10      05/16/83
380  !
390  ! Model #   Description                                  Address Code
400  !
410  ! 2631G     HP-IB Graphics Character Printer                 01
420  ! 59313A    Analog to Digital Converter                      06
430  ! 59306A    Relay Actuator                                   16
440  !
450  ! 0.1     HPIB DEVICE ADDRESSES      Select Code #7       05/16/83
460  !
470  ! Model #   Description                                  Address Code
480  !
490  ! 59303A    Digitial to Analog Converter        Data         02
500  !               S/N 2144A01860                  Command      03
510  ! 8620C     Sweep Oscillator                                 06
520  ! 8660B     Synthesized Signal Generator                     19
530  ! 436A      Power Meter S/N 1930A06521  (8181A Sensor       14
540  !                                       S/N 1926A18038)
550  ! 436A      Power Meter S/N 1930A06577  (8181A Sensor       15
560  !                                       S/N 1926A18041)
570  ! 11713A    Attenuator/Switch Driver                         28
580  !
590  ! 1.0   C O M M O N,  D A T A  T Y P E  D E F I N I T I O N S  A N D
```

```
600   !
610   !                  P R O G R A M   I N I T I A L I Z A T I O N
620   !
630   !
640   ! 1.1                    S T O R A G E   A L L O C A T I O N
650   !
660   COM SHORT Le,Lh,Pdbm,Pmval,Pg,Al,Bl,Ampgain
670   COM INTEGER A(730),X2,Prcnt_am,Band
680   COM Title$[80],Oper$[80],Sys$[1]
690   SHORT Freqz(500),Scale,Pmf,Pmr,Volts,Valx,X1,X,Samp(900),Plotdb(900)
700   SHORT Avgi(500),Errdbi(500),Pmini(500),Pmaxi(500),Cf,S
710   SHORT Pre_err(500),Post_err(500),Zw(300),Status
720   INTEGER I,Year,B(900),Dir(900),Px1(2,3),Px2(3),Py1(2,3),Py2(3),Cond,N
730   INTEGER Slen,Samp_size,N1
740   DIM Units$(1:4,1)[25],Z$[50],Xlabel$[40]
750   !
760   ! 1.2              A S S I G N M E N T   O F   V A R I A B L E S
770   !
780   FOR I=1 TO 5
790   READ Xlabel
800   Xlabel$=Xlabel$&VAL$(Xlabel)&CHR$(179)&"  "
810   NEXT I
820   READ Px1(*),Px2(*),Py1(*),Py2(*)
830   DATA 180,270,360,90,180, 15,75,15,75, 55,330,55,330, 125,395,125,395, 50,1
10,50,110, 55,55,10,10, 232,232,27,27, 387,387,185,185, 85,85,40,40
840   !
850 Horn_data:  !
860   !
870   !                                                    Min     Max
880   !   Horn #     Al       Bl      Lh        Le       Freq    Freq
890   !
900   DATA  638,    3.73,    2.93,   6.90,     5.94,   18.00,   26.5
910   DATA  639,    5.56,    4.28,   9.56,     9.26,   12.40,   18.0
920   DATA  640,    7.35,    5.50,  13.094,   10.991,   8.20,   12.4
930   DATA  642,   11.25,    8.30,  19.946,   17.448,   5.40,    8.2
940   DATA  643,   15.25,   11.25,  27.731,   23.186,   3.95,    5.85
950   DATA  644,   23.10,   17.20,  40.476,   34.914,   2.60,    3.95
960   DATA  645,   35.10,   25.95,  62.122,   53.113,   1.70,    2.6
970   DATA  646,   53.10,   39.25,  92.771,   79.947,   1.12,    1.7
980   !
990 ! S$=CHR$(190)          ! ** May be used as squared symbol **
1000  S$="^2"               ! ** Current definition for squared symbol **
1010  Esc$=CHR$(27)         ! ** ASCII code 27 used for escape sequences to
1020                        !    2631G printer **
1030  !
1040  C=3E10                !Speed of light in Centimeters
1050  !
1060  Units$(1,0)="V"&S$&"/m"&S$
1070  Units$(1,1)="A"&S$&"/m"&S$
1080  Units$(2,0)="V/m"
1090  Units$(2,1)="A/m"
1100  Units$(3,0)="mW/cm"&S$
1110  Units$(3,1)="mW/cm"&S$
1120  Units$(4,0)="dBV/m"
1130  Units$(4,1)="dBA/m"
1140  !
1150  Max_try=2             ! ** Maximum Number of Trys to Set Power Meters **
1160  Slen=700              ! ** Initial value for sample length **
1170  Store$=":X12,0,0"     ! ** Default Mass Storage Device **
1180  Quote$=CHR$(34)
```

```
                                                !enter frequencies into array Freq(*)
1790  GOSUB Get_freq
1800  !
1810  ! 2.23  Select the Waveguide to use
1820  !
1830  INPUT "Enter NARDA Horn Model (640, 642, 643, 644, or 645)",Wr
1840  FOR I=1 TO 8
1850  READ Thorn,Al,Bl,Lh,Le,Min_freq,Max_freq
1860  IF Thorn=Wr THEN 1910
1870  NEXT I
1880  RESTORE Horn_data
1890  CALL Dcol("Only 640, 642, 643, 644, or 645 are accepted responses, try ag
ain.")
1900  GOTO 1830
1910  Distance=.5     ! Probe Distance from Horn in Meters
1920  Ampgain=50
1930  PRINT "Dimensions for NARDA Horn #";Wr;LIN(1)
1940  PRINT "      A =";Al;"    B =";Bl;"    Lh =";Lh;"    Le =";Le;LIN(1)
1950  PRINT "                Frequency Range: ";Min_freq;"TO";Max_freq;"GHz"
1960  !
1970  ! 2.3     D E F I N E   T H E   F I E L D   T O   E S T A B L I S H
1980  !
1990  ! 2.31  Select Electric or Magnetic
2000  !
2010  Sel=0
2020  INPUT "Do you want to enter Electric(0) or Magnetic(1) field units?",Sel
2030  IF (Sel=0) OR (Sel=1) THEN 2090
2040  CALL Dcol("Only selections 0 or 1 are allowed, try again.")
2050  GOTO 2010
2060  !
2070  ! 2.32  Select the Units to use
2080  !
2090  IF Sel=0 THEN DISP "Enter units: (1) "&Units$(1,0)&", (2) V/M, (3) "&Uni
ts$(3,0)&", or (4) dBV/M";
2100  IF Sel=1 THEN DISP "Enter units: (1) "&Units$(1,1)&", (2) A/M, (3) "&Uni
ts$(3,1)&", or (4) dBA/M";
2110  N=3
2120  INPUT N
2130  IF (N<1) OR (N>4) THEN 2090
2140  !
2150  ! 2.33  Enter the Field and Convert to mW/cm^2
2160  !
2170  DISP "Enter Desired Field in "&Units$(N,Sel);
2180  INPUT Valx
2190  IF (N<>4) AND ((Valx<0) OR (Valx>1.0E8)) THEN 2090
2200  IF (N=4) AND (Valx>100) THEN 2090
2210  Inval=Valx
2220  IF N=2 THEN Valx=Valx*Valx
2230  IF (N=3) AND (Sel=0) THEN Valx=3767*Valx
2240  IF (N=3) AND (Sel=1) THEN Valx=Valx/37.67
2250  IF N=4 THEN Valx=10^(Valx/20)^2
2260  !
2270  IF Sel=0 THEN Setx=Valx/3767      !mW for power calculations
2280  IF Sel=1 THEN Setx=Valx*37.67
2290  INPUT "Enter Meter Full Scale Voltage",Fsvolts
2300  IF Fsvolts>5 THEN 2290
2310  DISP "Enter Meter Full Scale Field in "&Units$(N,Sel);
2320  INPUT Fsval
2330  IF N=4 THEN INPUT "Enter scale range in dB",Fsrange
2340  !
2350  ! 2.34  Computer Selects the proper A/D Channel
```

```
!
Cn=2
Cnset=3.5 !Volts
IF ABS(Fsvolts))1 THEN 2420
Cn=1
Cnset=1 !Volts
Conv=Cnset/1022
Instr$="H"&VAL$(2^(Cn-1))&"AJ"      !command to sample channel 'Cn'
PRINT LIN(2);"CAUTION"
PRINT "   1. Check Hardware Status before CONTinuing"
DISP "Connect meter recorder output to Ch# ";VAL$(Cn);". Press CONTinue wh
eady."
PAUSE
!
! 3.0                    P R O G R A M   E X E C U T I O N
!
! 3.1  I N I T I A L I Z E   E Q U I P M E N T   F O R   E X E C U T I O N
!
! 3.11  Position Probe
!
Mdir=1
OUTPUT Card,6;"H4AJ"
Dig=SHIFT(READBIN(Card,6),-8)+READBIN(Card,6)
IF Dig<15 THEN Start
DISP "Positioning Probe."
GOTO 2560
!
! 3.12  Setup HORNGO Screen
!
Start: DISP
Gp=0
GOSUB Setup_screen
!
FOR I=0 TO Tf
Try=1
Cf=Freqz(I)
Lambda=C/(Cf*1E9)
Ad=Al/Lambda
Bd=Bl/Lambda
Alh=Lh/Lambda
Dist_norm=Distance/Lambda*100
Ale=Le/Lambda
Alpha=Ad*Ad*(1/Alh+1/Dist_norm)
Beta=Bd*Bd*(1/Ale+1/Dist_norm)
Rh=.01*Alpha*(1+10.19*Alpha+.51*Alpha^2-.097*Alpha^3)
Re=.1*Beta^2*(2.31+.053*Beta)
Gain=10*LGT(Ad*Bd)+10.08-Rh-Re
Gain_ratio=10^(Gain/10)
F=FNC(Cf*1E9,F$,2)
Pz=Setx*4*PI*(Distance*100)^2/Gain_ratio
Pz_dbm=10*LGT(Pz)
GOSUB Calibrate
Pg=Pz_dbm-Ampgain
Pmval=Pz_dbm-Cal_foward  !foward power meter setting without mismatch loss
!
! 3.13  Update Screen with Current Measurement Parameters
!
SWRITE 7,16,VAL$(F)&" "&F$&"    "
SWRITE 7,57,VAL$(PROUND(Pz/1000,-3))&" W   "
SWRITE 9,66,VAL$(Ampgain)&" dB"
```

```
2950  SWRITE 10,25,VAL$(PROUND(Pmval,-2))&" dBm    "
2960  SWRITE 11,32,"              "
2970  SWRITE 12,33,"              "
2980  SWRITE 14,1,RPT$(" ",55)
2990  !
3000  ! 3.14  Program Frequency and Amplitude on Selected Synthesizer
3010  !
3020  !                                                    ! ** CF on 8660B **
3030  IF Cf<2 THEN CALL Cfreq(Cf)
3040  IF Cf>=2 THEN GOSUB Set_freq
3050  GOSUB Set_meter
3060  !
3070  ! 3.2  R O T A T E   P R O B E   A N D   S A M P L E   R E S P O N S E
3080  !
3090  CALL Readhp(Pmr,15)
3100  Pf_dbm=Pmf+Cal_foward
3110  Pr_dbm=Pmr+Cal_reverse
3120  Rl_db=Pf_dbm-Pr_dbm
3130  Rho=10^(Rl_db/-20)
3140  Ml_db=-10*LGT(1-Rho*Rho)
3150  Pmval=Pz_dbm-Cal_foward+Ml_db
3160  SWRITE 10,25,VAL$(PROUND(Pmval,-2))&" dBm    "
3170  GOSUB Set_meter
3180  Pre_err(I)=PROUND(Pmf-Pmval,-2)
3190  IF ABS(Pre_err(I))<.1 THEN 3250
3200  Try=Try+1
3210  IF Try<=Max_try THEN 2870
3220  OUTPUT 728;"A123"
3230  DISP "System Malfunction Unable to set power meter."
3240  PAUSE
3250  SWRITE 11,33,VAL$(Pre_err(I))&" dB    "
3260  SWRITE 14,1,"Field Established in Range: "&VAL$(Inval)&" "&Units$(N,Sel)
3270  DISP "     Sampling data from rotation."
3280  REDIM Dir(Slen),B(Slen),Plotdb(Slen)
3290  MAT Dir=ZER
3300  MAT B=ZER
3310  IF Mdir>0 THEN OUTPUT Card,16;"B4A6"                    !probe clockwise
3320  IF Mdir<0 THEN OUTPUT Card,16;"B6A4"                !probe counter-clockwise
3330  !
3340  ! 3.21  Sample Data from Hazard Probe and Rotator Box
3350  !
3360  SUSPEND INTERACTIVE
3370  FOR J=0 TO Slen                                        !A/D Channel for Probe
3380     OUTPUT Card,6;Instr$
3390     ENTER Card,6 BFHS 2 NOFORMAT;B(J)
3400     OUTPUT Card,6;"H4AJ"                !A/D Channel for Rotator Position
3410     ENTER Card,6 BFHS 2 NOFORMAT;Dir(J)
3420  NEXT J
3430  RESUME INTERACTIVE
3440  FOR J=Slen-1 TO 400 STEP -1
3450     IF ABS(Dir(J)-Dir(J+1))>5 THEN 3510
3460     IF B(J)<=0 THEN Err21
3470  NEXT J
3480 Err19:  DISP "System Malfunction  Check rotator connections."
3490  PAUSE
3500  GOTO 2870
3510  IF J<Slen-2 THEN 3580
3520 Err18:  DISP "Program Malfunction  Sample size larger than";Slen
3530  PAUSE
3540  GOTO 2870
```

```
3550  !
3560  ! 3.22  Check for Power Meter Drift
3570  !
3580  CALL Readhp(Pmf,14)
3590  Post_err(I)=PROUND(Pmf-Pmval,-2)
3600  SWRITE 12,34,VAL$(Post_err(I))&" dB    "
3610  Mdir=-Mdir
3620  IF ABS(Post_err(I))).1 THEN 2870
3630  Power=0
3640  Setdb=10*LGT(Valx)
3650  Slen=J*1.1
3660  Samp_size=J
3670  !
3680  ! 3.24  Convert Values to Plotting Units
3690  !
3700  REDIM Dir(Samp_size),B(Samp_size),Plotdb(Samp_size)
3710  DISP "     Converting values for plotting. (Sample =";Samp_size;")"
3720  IF N<>4 THEN 3800
3730  FOR J=0 TO Samp_size
3740     Tmp=Fsval-Fsrange+B(J)*Conv/Fsvolts*Fsrange
3750     IF Mdir=-1 THEN Plotdb(J)=Tmp-Setdb
3760     IF Mdir=1 THEN Plotdb(Samp_size-J)=Tmp-Setdb
3770     Power=Power+10^(Tmp/20)^2
3780  NEXT J
3790  GOTO 3930
3800  Chv=1
3810  IF (N=3) AND (Sel=0) THEN Chv=3767
3820  IF (N=3) AND (Sel=1) THEN Chv=1/37.67
3830  FOR J=0 TO Samp_size
3840     Tmp=B(J)*Conv/Fsvolts*Fsval*Chv
3850     IF (N=3) OR (N=1) THEN Tmp=SQR(Tmp)
3860     IF Mdir=-1 THEN Plotdb(J)=20*LGT(Tmp)-Setdb
3870     IF Mdir=1 THEN Plotdb(Samp_size-J)=20*LGT(Tmp)-Setdb
3880  !
3890  ! 3.25  Sum up Powers and Compute Average
3900  !
3910     Power=Power+Tmp*Tmp
3920  NEXT J
3930  Avg=Power/Samp_size
3940  Errdb=10*LGT(Avg)-Setdb
3950  IF (N=2) OR (N=4) THEN Avg=SQR(Avg)
3960  IF N=3 THEN Avg=Avg/Chv
3970  IF N=4 THEN Avg=20*LGT(Avg)
3980  !
3990  ! 4.0              G R A P H I C S   A N D   T A B L E S
4000  !
4010  MAT SEARCH Plotdb(*),MIN;Pmini(I)
4020  MAT SEARCH Plotdb(*),MAX;Pmaxi(I)
4030  Avgi(I)=Avg
4040  Errdbi(I)=Errdb
4050  DISP
4060  GRAPHICS
4070  IF Gp>0 THEN 4330
4080  PLOTTER IS "GRAPHICS"
4090  DEG
4100  !
4110  ! 4.1              I N I T I A L I Z E   G R A P H I C S
4120  !
4130  ! 4.11  Plotting Titles
4140  !
```

```
4150  LORG 6
4160  CSIZE 4.55,7/15
4170  MOVE 60,100
4180  LABEL USING "#,K";Title$
4190  CSIZE 3.1,8/15
4200  MOVE 29,94
4210  LABEL USING "#,K";"Applied Field: "&VAL$(Inval)&" "&Units$(N,Sel)
4220  MOVE 93,94
4230  LABEL USING "#,K";"Meter Full Scale: "&VAL$(Fsval)&" "&Units$(N,Sel)
4240  IF I>0 THEN 4330
4250  !
4260  ! 4.12  Program Printer for Perforation Skip, and Dump Title
4270  !
4280  OUTPUT Card,Printer USING "#,K";CHR$(12)&CHR$(10)&Esc$&"&l66p55f6d1L"
4290  DUMP GRAPHICS #Card,Printer;90,100
4300  !
4310  ! 4.13  Setup Plotting Parameters, and Scales
4320  !
4330  LOCATE Px1(0,Gp),Px2(Gp),Py1(0,Gp),Py2(Gp)
4340  IF I=8 THEN OUTPUT Card,Printer USING "#,K";Esc$&"&l66p50f6d1L"
4350  Smin=PROUND(Pmini(I)-.5,0)        !round to nearest dB
4360  Smax=PROUND(Pmaxi(I)+.5,0)
4370  SCALE 0,Samp_size,Smin,Smax
4380  FRAME
4390  CSIZE 2.25,7/15
4400  GPRINT Px1(2,Gp),Py1(2,Gp),VAL$(Cf)&" GHz"
4410  Y_corr=(Smax-Smin)*.11             ! ** Y correction factor **
4420  X_corr=Samp_size*.13               ! ** X correction factor **
4430  Grid_x=Samp_size/4+1E-4            ! ** X Grid spacing **
4440  Grid_y=Smax-Smin-1                 ! ** Y Grid spacing **
4450  GPRINT Px1(1,Gp),Py1(1,Gp),Xlabel$ ! ** Draw X labels **
4460  AXES Grid_x,Grid_y,0,Smin
4470  LORG 8
4480  FOR L=Smin TO Smax                 ! ** Draw Y labels **
4490     MOVE 0,L
4500     LABEL USING "#,MDZ,X";L
4510  NEXT L
4520  MOVE 0,Errdb
4530  DRAW Samp_size,Errdb
4540  MOVE 0,Smin
4550  !
4560  ! 4.15  Plot converted data
4570  !
4580  FOR J=0 TO Samp_size
4590     PLOT J,Plotdb(J)
4600  NEXT J
4610  LDIR 90
4620  LORG 5
4630  MOVE -X_corr,(Smin+Smax)/2
4640  LABEL USING "#,K";"dB Error"
4650  LDIR 0
4660  Gp=Gp+1
4670  IF Gp<4 THEN 4710
4680  LIMIT 0,184,0,148
4690  DUMP GRAPHICS #Card,1;2.25,90
4700  Gp=0
4710  EXIT GRAPHICS
4720  NEXT I
4730  !  System is closed down by turning on maximum attenuation on switch
4740  !  driver. DAC is left open to the previous programmed setting in the
```

```
4750  !  in the event the user wishes to restore the field manually.
4760  OUTPUT 728;"A123"
4770  GRAPHICS
4780  LIMIT 0,184,0,148
4790  IF (Gp>2) AND (Gp<4) THEN DUMP GRAPHICS #Card,Printer;2.25,90
4800  IF Gp<2 THEN DUMP GRAPHICS #Card,Printer;50,90
4810  EXIT GRAPHICS
4820  !
4830  ! 4.2                P R I N T   R E P O R T   S U M M A R Y
4840  !
4850  PRINTER IS Card,Printer,WIDTH(132)
4860  PRINT PAGE;LIN(4);TAB((81-LEN(Title$))/2);Title$;LIN(1)
4870  PRINT Day$;"   ";Month$;" ";Date$[5;2];",";Year;TAB(54);"Start Time:";Time
$;LIN(1)
4880  PRINT "Operator: ";Oper$;TAB(59);"Horn Model: ";VAL$(Wr)
4890  !
4900  ! 4.21  Rotation Statistics
4910  !
4920  PRINT LIN(3);TAB(35);"Rotation Statistics";LIN(2)
4930  PRINT " Freq.     Avg. Reading     Avg. Error     Low Error     High Error    H
igh-Low Error"
4940  PRINT " (GHz)       (";Units$(N,Sel)[1,7];")";TAB(30);"(dB)          (dB)
      (dB)            (dB)";LIN(1)
4950  FOR I=0 TO Nf-1
4960  PRINT USING 4990;Freqz(I);PROUND(Avgi(I),-3);Errdbi(I);Pmini(I);Pmaxi(I);P
maxi(I)-Pmini(I)
4970  NEXT I
4980  PRINT LIN(1);"Applied Field = ";PROUND(Inval,-3);Units$(N,Sel)
4990  IMAGE DDD.DDD,4X,SDZ.DDD,5X,MDZ.DD,8X,MDZ.DD,7X,MDZ.DD,10X,MDZ.DD
5000  !
5010  ! 4.34  Setting Error Summary
5020  !
5030  PRINT PAGE;LIN(1);TAB((55-LEN(Title$))/2);Title$
5040  PRINT LIN(2);TAB(15);"Power Meter Setting Error";LIN(2)
5050  PRINT "                          Pre-Rotation      Post-Rotation"
5060  PRINT "       Frequency          Setting Error     Setting Error"
5070  PRINT "         (GHz)                (dB)              (dB)";LIN(1)
5080  IMAGE 6X,3D.3D,8X,MDZ.DD,12X,MDZ.DD,10X,3D.3D
5090  FOR I=0 TO Tf
5100  PRINT USING 5080;Freqz(I),Pre_err(I),Post_err(I)
5110  NEXT I
5120  CALL Summary_plot(Title$,Tf,Freqz(*),Pmini(*),Pmaxi(*),Errdbi(*))
5130  !
5140 Save_file: !
5150  A$="N"
5160  INPUT "Would you like to SAVE this measurement (YES or NO)?",A$
5170  A$=UPC$(TRIM$(A$[1;1]))
5180  IF A$="N" THEN 5550
5190  IF A$()"Y" THEN Save_file
5200  LINPUT "Enter the File Name to SAVE data on.",File$[1;6]
5210  ASSIGN #1 TO File$,Status
5220  ON ERROR GOTO Errors
5230  IF Status()0 THEN 5310
5240     A$=Null$
5250     DISP "FILE: ";File$&Store1$;" already exists. OK to Re-write File (YES
 or NO)?";
5260     INPUT A$
5270     A$=UPC$(TRIM$(A$[1;1]))
5280     IF A$="N" THEN Save_file
5290     IF A$()"Y" THEN 5240
```

```
5300      GOTO Write
5310   IF Status()1 THEN 5350
5320      CREATE File$,15
5330      ASSIGN #1 TO File$
5340      GOTO Write
5350   IF Status()2 THEN Write
5360      DISP "Enter the Protect Code for ";File$;
5370      INPUT Prot$
5380      ASSIGN #1 TO File$,Status,Prot$
5390      GOTO 5230
5400 Write: !
5410      PRINT #1;Title$,Date$,Time$,Oper$,Wr,Sel,N,Inval,Valx,Fsvolts,Fsval,Fsr
ange,Version$
5420      FOR I=1 TO Tf
5430         PRINT #1;Freqz(I),Pre_err(I),Post_err(I),Pmini(I),Pmaxi(I),Avgi(I),E
rrdbi(I)
5440      NEXT I
5450   ASSIGN #1 TO *
5460   DISP "DATA HAS BEEN STORED SUCCESSFULLY."
5470   WAIT 2000
5480   PRINT LIN(1);"Data has been written to: ";File$&Store$
5490   ON ERROR GOSUB Err20
5500   GOTO 5550
5510 Errors: !
5520   IF ERRN()59 THEN Err20
5530      PRINT "File ";File$;" is not large enough. "
5540      GOTO Save_file
5550   GOSUB Get_freq
5560   GOTO Start
5570   END
5580   !
5590   ! 5.0              I N - L I N E   S U B R O U T I N E S
5600   !
5610 Set_meter: IF Cf<2 THEN 5970
5620   DISP "      Setting Power Meter."
5630   N1=INT(ABS(Pg))+10
5640   OUTPUT 703;"E0"
5650   OUTPUT 702;"999"
5660   X1=-1000
5670   CALL Coarse(N1)
5680   WAIT 5000
5690   CALL Readhp(Pmf,14)
5700   IF Pmf<=Pmval THEN 5740
5710   IF Pmf=-30 THEN 5850
5720   N1=N1+10
5730   GOTO 5670
5740   High=999
5750   Low=-999
5760   X2=(High+Low)/2
5770   OUTPUT 702;VAL$(INT(X2))
5780   CALL Readhp(Pmf,14)
5790   IF (X1>X2) AND (Prev_pmf>Pmf) THEN Err6
5800   IF ABS(Pmval-Pmf)<.02 THEN RETURN
5810   IF Pmf>Pmval THEN Low=X2
5820   IF (N1<=0) AND (INT(X2)<-995) THEN Err7
5830   IF Pmf<Pmval THEN High=X2
5840   IF ABS(High-Low)>3 THEN 5870
5850   N1=N1-10
5860   GOTO 5650
5870   X1=X2
```

```
5880  Prev_pmf=Pmf
5890  GOTO 5760
5900  !
5910 Err7:    DISP "System Malfunction System wide open - unable to set power.
"
5920  GOTO Abort
5930 Err6:    DISP "System Malfunction Amplifier saturated - unable to set pow
er."
5940 Abort: !
5950  OUTPUT 728;"A123"
5960  STOP
5970  High=Low=0
5980  CALL Setam(0)
5990  CALL Setamp(INT(Pg))
6000  CALL Readhp(Pmf,14)
6010  DISP "     Setting Power Meter:";Pmf;" (Coarse)"
6020  IF High AND Low THEN Fine
6030  IF Pmf)=Pmval THEN 6070
6040  Pg=Pg+1
6050  High=1
6060  GOTO 5990
6070  IF High THEN Fine
6080  Pg=Pg-1
6090  Low=1
6100  GOTO 5990
6110 Fine:    High=99
6120  Low=0
6130  X2=(High+Low)/2
6140  CALL Setam(X2)
6150  CALL Readhp(Pmf,13)
6160  DISP "     Setting Power Meter:";Pmf;" (Fine)"
6170  IF (ABS(Pmval-Pmf)(.03) OR (ABS(High-Low)(2) THEN RETURN
6180  IF Pmf)Pmval THEN Low=X2
6190  IF Pmf(Pmval THEN High=X2
6200  GOTO 6130
6210 Get_freq: ! Enter Frequencies from the Keyboard
6220  !
6230  EXIT GRAPHICS
6240  Nf=500   !Maximum Number of Frequencies
6250  REDIM Freqz(Nf),Avgi(Nf),Errdbi(Nf),Pmini(Nf),Pmaxi(Nf),Pre_err(Nf)
6260  REDIM Post_err(Nf)
6270  CALL Enterf(Nf,Freqz(*))
6280  Tf=Nf-1
6290  REDIM Freqz(Tf),Avgi(Tf),Errdbi(Tf),Pmini(Tf),Pmaxi(Tf),Pre_err(Tf)
6300  REDIM Post_err(Tf)
6310  RETURN
6320 Calibrate:  !
6330  IF Cf)4 THEN 6370
6340  Cal_foward=.90606*Cf^4-9.06729*Cf^3+31.9902*Cf^2-46.5373*Cf+52.99361
6350  Cal_reverse=.939396*Cf^4-9.3717*Cf^3+32.9685*Cf^2-47.81*Cf+43.94
6360  RETURN
6370  IF Cf)8 THEN 6410
6380  Cal_foward=-.0584512*Cf^3+1.3509968*Cf^2-9.719459*Cf+52.002673
6390  Cal_reverse=-.0275421*Cf^3+.7753252*Cf^2-6.386103*Cf+35.926958
6400  RETURN
6410  Cal_foward=.0017077*Cf^4-.07846*Cf^3+1.4525*Cf^2-12.244*Cf+67.136
6420  Cal_reverse=.01490293*Cf^3-.321051*Cf^2+1.95395*Cf+18.804
6430  SWRITE 18,10,"Cal_foward="&VAL$(Cal_foward)&"   Cal_reverse="&VAL$(Cal_rev
erse)
6440  RETURN
```

```
6450  !
6460 Setup_screen: ! Setup the HORNGO Screen
6470  !
6480  PRINTER IS 16
6490  EXIT GRAPHICS
6500  SCREATE 20,32
6510 Sub_setup: SWRITE 1,19,"Anechoic Range Automatic Control System"
6520  SWRITE 4,1,Day$&"   "&Month$&" "&Date$[5;2]&","&VAL$(Year)
6530  SWRITE 4,55,"Start Time:"&Time$
6540  SWRITE 6,1,"System Parameters"
6550  SWRITE 6,50,"Horn #: MODEL "&VAL$(Wr)
6560  SWRITE 7,5,"Frequency:"
6570  SWRITE 7,50,"Power:"
6580  SWRITE 9,50,"Amplifier Gain:"
6590  SWRITE 9,1,"Power Meter Parameters"
6600  SWRITE 10,5,"Calculated Setting:"
6610  SWRITE 11,5,"Pre-Rotation Setting Error:"
6620  SWRITE 12,5,"Post-Rotation Setting Error:"
6630  SWRITE 20,1,"System Status"
6640  RETURN
6650 Set_freq: !
6660  Max_low=2
6670  Max_high=18.6
6680  CALL Setamp(10)
6690  IF (Cf<Max_low) OR (Cf>Max_high) THEN Err17
6700  CALL Set_freq_8620(Cf,Band)
6710  S=Cf/Band-.02
6720  S=PROUND(S/(INT(S/1.3)+1),-6)*1000
6730  CALL Cfreq(S)
6740  RETURN
6750  !
6760  ! Miscellanous Program Errors
6770  !
6780 Err17:  DISP "Program Malfunction Error in setting frequency on 8620"
6790  PAUSE
6800  STOP
6810 Err21:  DISP "System Malfunction Check meter connections."
6820  PAUSE
6830  RETURN
6840 Err20:  DISP "Program Malfunction Program Error: ";ERRM$
6850  GOTO 6840
6860 ! END                                                          ***Dcol
6870  !
6880  SUB Dcol(A$)!
6890  !
6900  ! SUB Dcol(A$)
6910  !     A$      String to Display
6920  !
6930  Size=LEN(A$)
6940  FOR I=0 TO Size-1
6950     DISP TAB(Size-I);A$[1,I+1]
6960     WAIT 75
6970  NEXT I
6980  FOR I=1 TO 3
6990     WAIT 325
7000     DISP A$[2]
7010     WAIT 325
7020     DISP A$
7030     BEEP
7040  NEXT I
```

```
7050  WAIT 40*Size
7060  SUBEXIT
7070  SUBEND
7080  !                                                          ***Cfreq
7090  SUB Cfreq(SHORT F_mhz)!
7100  !
7110  ! SUB Cfreq(SHORT F_mhz)
7120  !      F_mhz    Frequency in MHz
7130  !
7140  ! Description
7150  !      Set the Center Frequency on the 8660B
7160  !
7170  Cmd$=VAL$(1E-10*INT(F_mhz*1E6))
7180  OUTPUT 719;"/I"&REV$(Cmd$[2])&"("
7190  SUBEXIT
7200  SUBEND
7210  !
7220 Set_amp_8660: !                                    ***Set_amp_8660
7230  SUB Setamp(INTEGER Amp_dbm)!
7240  !
7250  !     Amp_dbm    Amplitude in dBm
7260  !
7270  ! Description
7280  !     Set the Amplitude on the 8660B to Amp_dbm
7290  !
7300  Amp$=VAL$(ABS(1E-3*(Amp_dbm-13)))&"000"
7310  Cmd$="/"&REV$(Amp$[2,4])&"C"
7320  OUTPUT 719;Cmd$
7330  SUBEXIT
7340  SUBEND
7350  !
7360 Set_am_mod_8660: !                          ***Set_am_mod_8660
7370  SUB Setam(INTEGER Prcnt)!
7380  !
7390  ! SUB Setam(INTEGER Prcnt)
7400  !     Prcnt    Setting for 8660B Percent Amplitude Modulation
7410  !
7420  P$=VAL$(ABS(Prcnt))
7430  IF LEN(P$)<2 THEN P$="0"&P$
7440  Cmd$="48$"&REV$(P$)&"%"
7450  OUTPUT 719;Cmd$
7460  SUBEXIT
7470  SUBEND
7480  !                                                          ***Time
7490  SUB Time(Date$,Time$,Day$,Month$,INTEGER Year,Type)!
7500  !
7510  ! SUB Time(Date$,Time$,Day$,Month$,INTEGER Year,Type)
7520  !     Date$    The current Date in the form " YY/MM/DD."
7530  !     Time$    The current Time in the form " HH.MM.SS." when Type=1
7540  !              or "HH:MM xM" when Type=2
7550  !     Day$     The day of the week
7560  !
7570  DIM Day$(6)[9],Month$(1:12)[9]
7580  INTEGER Month,Day,Hour,Minute,Sec,Weekday,Year_
7590  READ Day$(*),Month$(*)
7600  DATA Saturday,Sunday,Monday,Tuesday,Wednesday,Thursday,Friday
7610  DATA January,February,March,April,May,June,July,August,September
7620  DATA October,November,December
7630  Year=1983
7640  OUTPUT 9;"Recall time"
```

```
7650  ENTER 9;Month,Day,Hour,Minute,Sec
7660  Month$=Month$(Month)
7670  OUTPUT Date$ USING Date_format;Month,Day,Year-1900
7680  IF Type=2 THEN 7710
7690     OUTPUT Time$ USING Time_format1;Hour,Minute,Sec
7700  GOTO 7750
7710     M$="AM"
7720     IF Hour>11 THEN M$="PM"
7730     IF (Hour>12) OR (Hour=0) THEN Hour=ABS(Hour-12)
7740     OUTPUT Time$ USING Time_format2;Hour,Minute,M$
7750  Year_=Year-(Month<3)
7760  Month=Month+12*(Month<3)
7770  Year_=INT(1.25*Year_)-INT(Year_/100)+INT(Year_/400)
7780  Weekday=INT(Day+2.6*(Month+1)+Year_) MOD 7
7790  Day$=Day$(Weekday)
7800  SUBEXIT
7810  !
7820 Date_format:     IMAGE #,1X,ZZ,"/",ZZ,"/",ZZ,"."
7830 Time_format1:    IMAGE #,1X,ZZ,".",ZZ,".",ZZ,"."
7840 Time_format2:    IMAGE #,1X,DD,":",ZZ," ",AA
7850  SUBEND
7860  !                                                          ***FNC
7870  DEF FNC(V,F$,Pr)!
7880  !
7890  ! DEF FNC(V,F$,Pr)
7900  !      V   Numeric value
7910  !      F$  String equivalent
7920  !      Pr  Power Rounding Factor
7930  !
7940  ! Description
7950  !      Use internally to convert Hz to kHz, Mhz, GHz, etc.
7960  !
7970  DIM Nm$(-1:3)[3]
7980  READ Nm$(*)
7990  DATA mHz,Hz,kHz,MHz,GHz
8000  I=INT(LGT(V)/3)
8010  F$=Nm$(I)
8020  RETURN PROUND(V/10^(I*3),-Pr)
8030  FNEND
8040  !                                                          ***Readhp
8050  SUB Readhp(SHORT Power,INTEGER Paddr)!
8060  !
8070  ! SUB Readhp(SHORT Power,INTEGER Paddr)
8080  !      Power    Power read from the HP Power Meter in dBm
8090  !      Paddr    Adress of the Power Meter
8100  !
8110  DIM Err$[65]
8120 Start: !
8130  FOR X=1 TO 20
8140     OUTPUT 7,Paddr;"D-V"
8150     WAIT (Range=73)*4000
8160     ENTER 7,Paddr USING "B,B,X,F";Status,Range,Power
8170     IF Status=80 THEN 8260
8180        Err$="Power Meter Malfunction."
8190        IF (Status=81) OR (Status=83) THEN SUBEXIT
8200        IF Status=82 THEN Err$="Meter Over Range."
8210        BEEP
8220        DISP "HP436A - "&Err$
8230        PAUSE
8240        DISP
```

```
8250      GOTO Start
8260      IF (X<>i) AND (ABS(Power-Pi)<=.02) THEN 8300
8270         Pi=Power
8280   NEXT X
8290   DISP "POWER METER NOT SETTLED"
8300   LOCAL i0,Paddr
8310   SUBEXIT
8320   SUBEND
8330   !                                                          ***Enterf
8340   SUB Enterf(Nfreq,SHORT Freqx(*))!
8350   !
8360   ! SUB Enterf(Nfreq,SHORT Freqx(*))
8370   !      Nfreq    Number of Frequencies that were entered
8380   !      Freqx(*) The actual frequency values
8390   !
8400   ! Description
8410   !      Subroutine to enter frequencies from the keyboard inti the program
8420   !
8430   DIM Z$[25],A$[160]
8440   PRINTER IS 16
8450 Enter_freq: Nf=0
8460   Z$="R"
8470   INPUT "Do you want to enter seperate frequencies or a range? (S or R)",Z
$
8480   IF Z$[i;i]="R" THEN Range
8490   IF Z$[i;i]<>"S" THEN 8460
8500   ON ERROR GOTO Bad_number
8510   !
8520   ! Enter frequencies Seperatly
8530   !
8540   Z$=Null$
8550   A$=Null$
8560   DISP "Enter Frequency (GHz) #";Nf+i;Z$;
8570   LINPUT A$
8580   Size=LEN(A$)
8590   IF Size=0 THEN Exit
8600   FOR I=i TO Size
8610      C=POS(A$[I,Size],",")
8620      IF C=0 THEN 8660
8630         X=C+I-2
8640         Freqx(Nf)=VAL(A$[I,X])
8650      GOTO 8670
8660         Freqx(Nf)=VAL(A$[I])
8670      IF (Freqx(Nf)>=i) AND (Freqx(Nf)<=18) THEN 8700
8680         CALL Dcol("Specified Frequency is out of Range, Try Again...")
8690         GOTO 8550
8700      Nf=Nf+i
8710      Z$="Press CONTinue to Exit"
8720      I=X+i
8730      IF C=0 THEN 8550
8740   NEXT I
8750   !
8760   ! Enter frequencies as a range
8770   !
8780 Range:  Inc=i
8790   INPUT "Enter Start, Stop, and Increment Frequencies (MHz)",Start,Stop,Inc
8800   IF (Start<i) OR (Stop>18) OR (Start>18) OR (Stop<i) THEN Range
8810   IF ABS(Stop-Start)/Inc+i<=Nfreq THEN 8840
8820   CALL Dcol("Too many Frequencies, Change dimension size.")
8830   GOTO Range
```

```
8840  FOR Freq=Start TO Stop STEP Inc
8850     Freqx(Nf)=Freq
8860     Nf=Nf+1
8870  NEXT Freq
8880 Exit:  IF Nf>0 THEN 8910
8890  CALL Dcol("No Frequencies Defined, Try Again...")
8900  GOTO Enter_freq
8910  Nfreq=Nf
8920  SUBEXIT
8930 Bad_number: !
8940  IF ERRN<>32 THEN 10559
8950  CALL Dcol("Illegal Numeric Response. Try Again...")
8960  GOTO 8550
8970  SUBEND
8980 Set_freq_8620: !                                    ***Set_freq_8620
8990  SUB Set_freq_8620(SHORT F_ghz,INTEGER Band) !
9000  SHORT Low_limit(1:3),Band_range(1:3),P1,P2
9010  READ Low_limit(*),Band_range(*),P1,P2
9020  DATA 2, 6, 12,    4.2, 6.4, 6.6,    6.1, 12.2
9030  Band=1+(F_ghz>P1)+(F_ghz>P2)-3*((F_ghz<2) OR (F_ghz>18.6))
9040  IF Band>0 THEN 9090
9050  A$="F_ghz="
9060  BEEP
9070  EDIT "8620C - Frequency Out of Range",A$
9080  GOTO 9030
9090  V=(F_ghz-Low_limit(Band))*10/Band_range(Band)
9100  V$=VAL$(INT(V*1000))&"E"
9110  IF V>9.9995 THEN V$="1000E"
9120  OUTPUT 706 USING 9130;Band,V$
9130  IMAGE "M1B",K,"V",K
9140  SUBEND
9150  !                                                  ***Coarse
9160 Coarse: !
9170  SUB Coarse(INTEGER N1)
9180  N=MIN(ABS(INT(N1/10)),7)
9190  A$="A"&RPT$("1",BIT(N,0))&RPT$("2",BIT(N,1))&RPT$("3",BIT(N,2))
9200  B$="B"&RPT$("1",NOT BIT(N,0))&RPT$("2",NOT BIT(N,1))&RPT$("3",NOT BIT(N,2)
)
9210  OUTPUT 728;RPT$(A$,LEN(A$)*1)&RPT$(B$,LEN(B$)*1)
9220  SUBEND
9230  !
9240 Summary_plot: !
9250  SUB Summary_plot(Title$,Tf,SHORT Freqz(*),Pmini(*),Pmaxi(*),Errdbi(*))
9260  !
9270  ! 4.3                    S U M M A R Y   G R A P H
9280  !
9290  INTEGER Point(Tf)
9300  PLOTTER IS "GRAPHICS"
9310  GRAPHICS
9320  DEG
9330  !
9340  ! 4.31  Setup Scaling, and Plotting Limits
9350  !
9360  LOCATE 20,120,10,93
9370  MAT SORT Freqz(*) TO Point
9380  Fmin=Freqz(Point(0))
9390  Fmax=Freqz(Point(Tf))
9400  MAT SEARCH Pmini(*),MIN;Smin
9410  MAT SEARCH Pmaxi(*),MAX;Smax
9420  Smin=PROUND(Smin-.5,0)
```

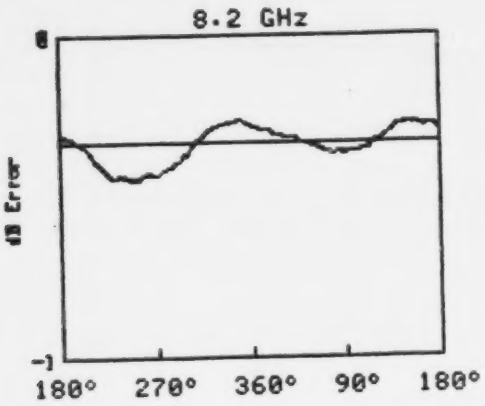
```
9430  Smax=PROUND(Smax+.5,0)
9440  IF Tf>0 THEN Fc=(Fmax-Fmin)/Tf
9450  IF Tf=0 THEN Fc=Fmax/2
9460  Fmin=Fmin-Fc
9470  Fmax=Fmax+Fc
9480  IF Fmin=Fmax THEN 14757
9490  SCALE Fmin,Fmax,Smin,Smax
9500  FRAME
9510  CSIZE 2.75
9520  Y_corr=(Smax-Smin)*.01
9530  X_corr=(Fmax-Fmin)*.02
9540  Xc=X_corr
9550  CLIP Fmin-X_corr,Fmin,Smin,Smax
9560  AXES Fc,1,Fmin,Smin
9570  UNCLIP
9580  LORG 8                                ! ** Label the Y axis **
9590  FOR I=Smin TO Smax
9600  MOVE Fmin-X_corr*2,I
9610  LABEL USING "#,MDZ";I
9620  NEXT I
9630  LORG 5
9640  LDIR 0
9650  FOR I=0 TO Tf STEP INT((Tf-1)/10)+1
9660  MOVE Freqz(I),Smin-Y_corr
9670  DRAW Freqz(I),Smin
9680  MOVE Freqz(I),Smin-Y_corr*3
9690  LABEL USING "#,K";Freqz(I)
9700  NEXT I
9710  CSIZE 2.50
9720  IF Tf>15 THEN X_corr=0
9730  FOR J=0 TO Tf
9740  I=Point(J)
9750  LINE TYPE 10
9760  MOVE Freqz(I),Pmini(I)
9770  DRAW Freqz(I),Pmaxi(I)
9780  DRAW Freqz(I),Pmini(I)
9790  LINE TYPE 1
9800  !
9810  ! 4.32  Mark the Average Error with a Circle
9820  !
9830  LORG 5
9840  LDIR 0
9850  MOVE Freqz(I),Errdbi(I)
9860  LABEL USING "#,K";"O"
9870  !
9880  ! 4.33  Label the Plot and Dump it to the Graphics Printer
9890  !
9900  LORG 4
9910  IF Tf>15 THEN LORG 2
9920  IF Tf>15 THEN LDIR 90
9930  MOVE Freqz(I)-X_corr,Pmaxi(I)+Y_corr
9940  LABEL USING "#,MDZ.DD";Pmaxi(I)
9950  MOVE Freqz(I)-X_corr,Pmini(I)-Y_corr
9960  LORG 6
9970  IF Tf>15 THEN LORG 8
9980  LABEL USING "#,MDZ.DD";Pmini(I)
9990  NEXT J
10000 X_corr=Xc
10010 LORG 5
10020 CSIZE 3.3
```

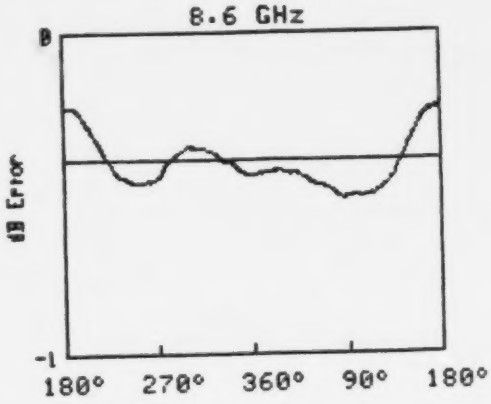
```
10030 LDIR 90
10040 MOVE Fmin-X_corr*6,(Smin+Smax)/2
10050 LABEL USING "#,K";"dB Error"
10060 LDIR 0
10070 Xi=(Fmin+Fmax)/2
10080 MOVE Xi,Smin-Y_corr*8
10090 LABEL USING "#,K";"Frequency (GHz)"
10100 CSIZE 4
10110 MOVE Xi,Smax+Y_corr*4
10120 LABEL USING "#,K";Title$
10130 PRINT PAGE
10140 DUMP GRAPHICS #10,1
10150 SUBEND
```

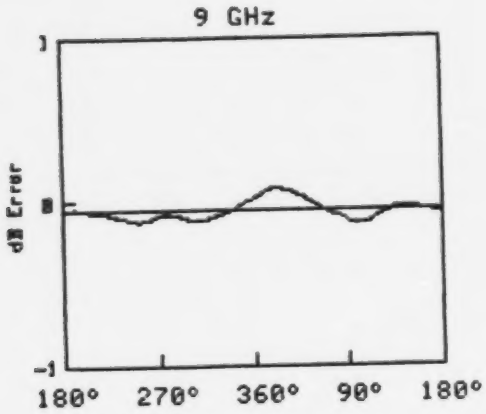
NARDA MODEL 8616 PROBE 8621 S/N 09008

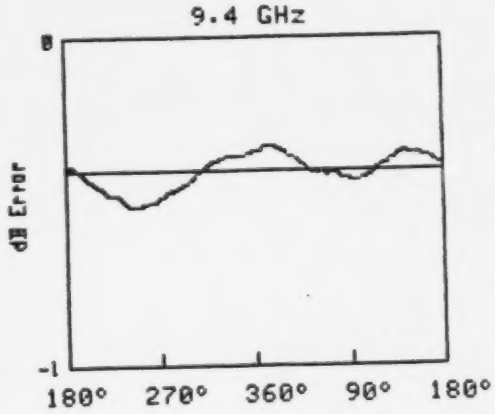
Applied Field: 1.5 mW/cm^2

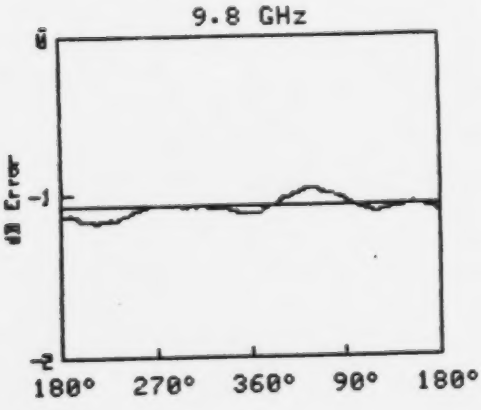
Meter Full Scale: 2 mW/cm^2

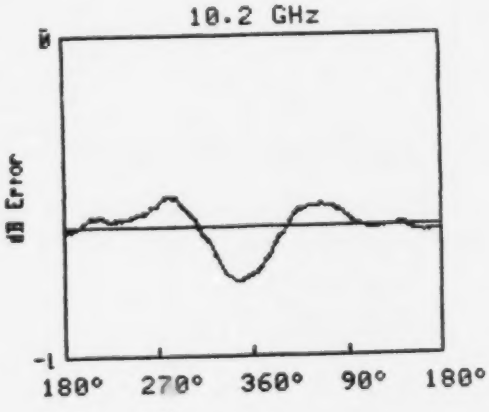


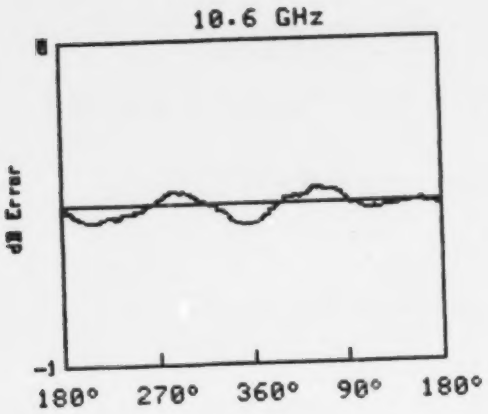


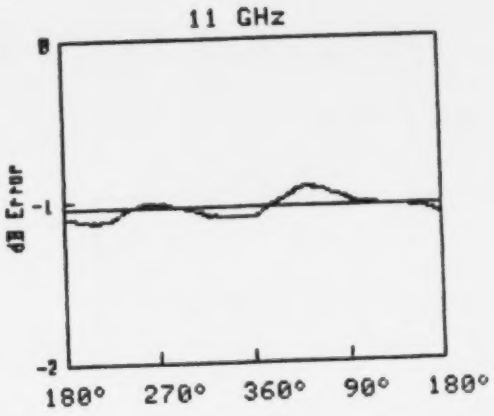


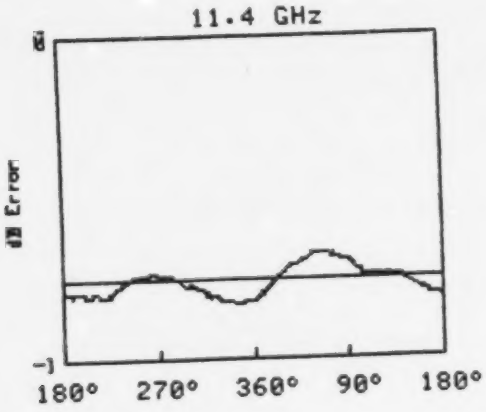


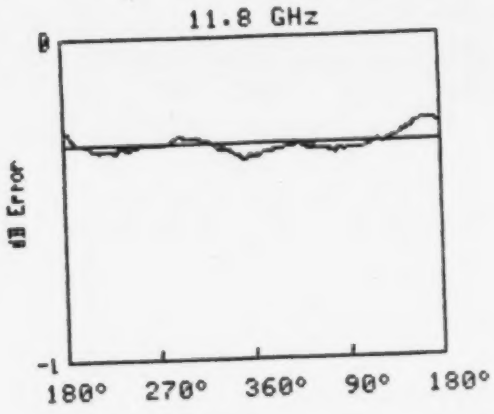


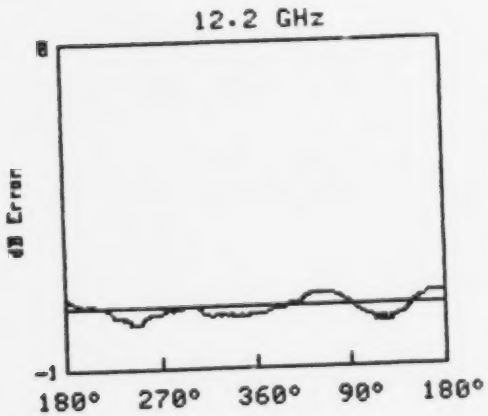



10.6 GHz
dB Error
0
-1
180° 270° 360° 90° 180°


11 GHz
dB Error
0
-1
-2
180° 270° 360° 90° 180°


11.4 GHz
dB Error
0
-1
180° 270° 360° 90° 180°


11.8 GHz
dB Error
0
-1
180° 270° 360° 90° 180°


12.2 GHz
dB Error
0
-1
180° 270° 360° 90° 180°

NARDA MODEL 8616 PROBE 8621 S/N 09008

THursday May 19, 1983 Start Time: 11:52 AM

Operator: MICHAEL R. MOLONY Horn Model: 640

Rotation Statistics

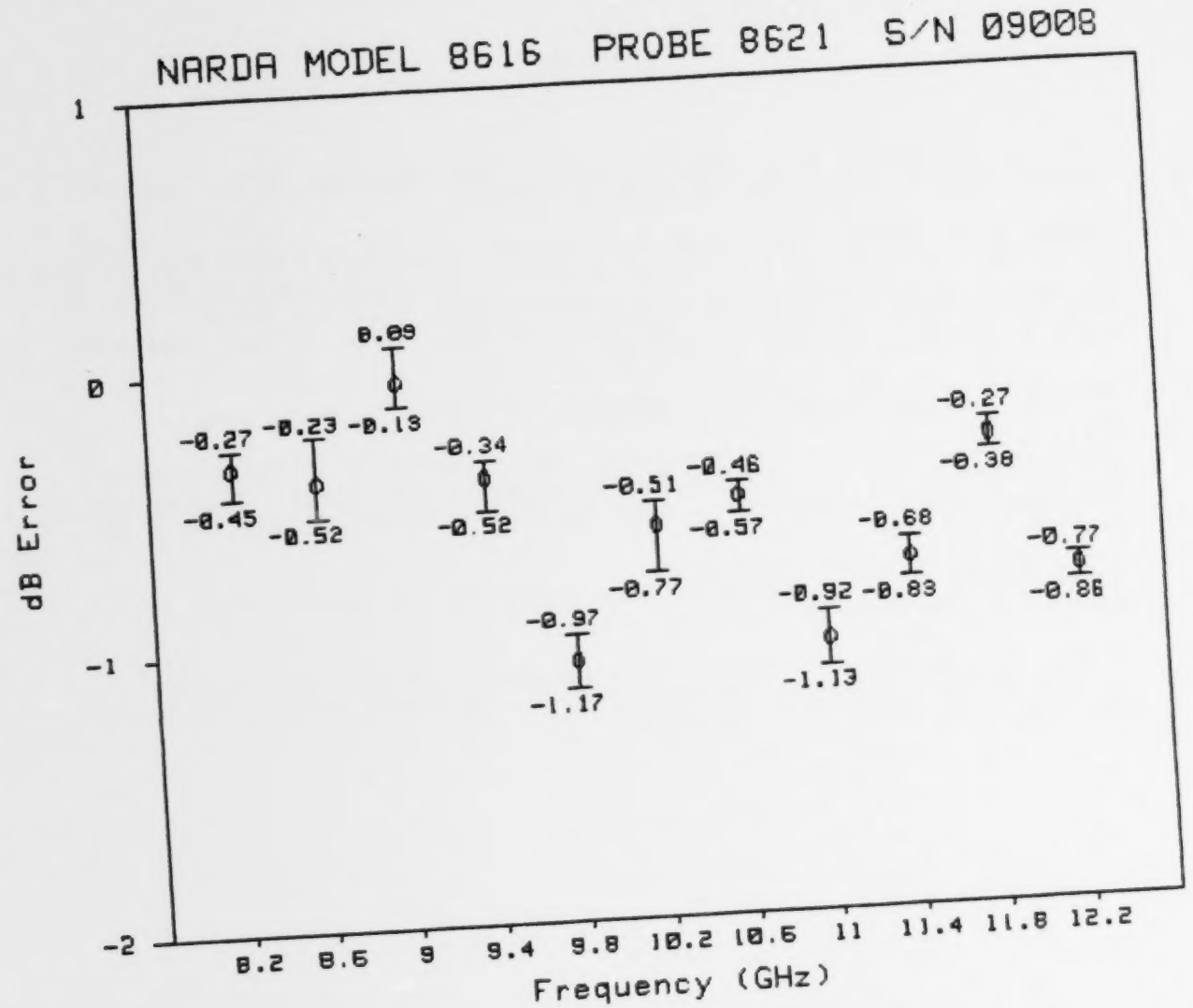
Freq. (GHz)	Avg. Reading (mW/cm^2)	Avg. Error (dB)	Low Error (dB)	High Error (dB)	High-Low Error (dB)
8.200	1.389	-0.33	-0.45	-0.27	0.18
8.600	1.369	-0.40	-0.52	-0.23	0.29
9.000	1.484	-0.05	-0.13	0.09	0.22
9.400	1.366	-0.41	-0.52	-0.34	0.18
9.800	1.172	-1.07	-1.17	-0.97	0.19
10.200	1.307	-0.60	-0.77	-0.51	0.26
10.600	1.335	-0.51	-0.57	-0.46	0.11
11.000	1.182	-1.03	-1.13	-0.92	0.20
11.400	1.261	-0.75	-0.83	-0.68	0.15
11.800	1.391	-0.33	-0.38	-0.27	0.11
12.200	1.244	-0.81	-0.86	-0.77	0.09

Applied Field = 1.5 mW/cm^2

NARDA MODEL 8616 PROBE 8621 S/N 09008

Power Meter Setting Error

Frequency (GHz)	Pre-Rotation Setting Error (dB)	Post-Rotation Setting Error (dB)
8.200	0.01	0.03
8.600	0.00	0.00
9.000	0.01	0.00
9.400	-0.02	-0.03
9.800	-0.01	-0.01
10.200	0.00	0.00
10.600	-0.01	-0.01
11.000	0.01	0.01
11.400	-0.01	-0.01
11.800	0.00	0.00
12.200	0.02	0.05


NARDA MODEL 8616 PROBE 8621 S/N 09008
1
0
-1
-2
dB Error
-0.27
-0.45
-0.23
-0.52
0.09
-0.13
-0.34
-0.52
-0.51
-0.77
-0.46
-0.57
-0.97
-1.17
-0.92
-1.13
-0.68
-0.83
-0.27
-0.38
-0.77
-0.86
8.2
8.6
9
9.4
9.8
10.2
10.6
11
11.4
11.8
12.2
Frequency (GHz)

REFERENCES

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